

NASA Contractor Report 3922(24)

USSR Space Life Sciences Digest

Issue 21

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Prepared for
NASA Office of Space Science and Applications
under Contract NASW-4292



National Aeronautics and
Space Administration
Office of Management
Scientific and Technical
Information Division

1989

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* Categories marked with * have no entries of their own, but refer readers to relevant abstracts in other categories.

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* Categories marked with * have no entries of their own, but refer readers to relevant abstracts in other categories.

To our readers: We are working in a large number of highly technical, specialized areas for which adequate Russian-English glossaries have yet to be compiled. We ask your help in improving the accuracy and specificity of our English terminology. Please fill out the form below whenever you encounter an incomprehensible, incongruous, awkward or otherwise inappropriate term. While we solicit all suggestions for improved renderings, the statement that a term is inappropriate provides us with useful information, even when no better alternative can be suggested. A copy of this form will appear in all future issues of the Digest. Thank you for your help.

Abstract Number	Incorrect or inappropriate term	Suggested rendering

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FROM THE EDITORS

This is Issue 21 of the USSR Space Life Sciences Digest. Readers will have noticed our new and, we are confident, improved look, made possible by our new computer system. Listing of individual abstract names in the table of contents of this issue is an innovation suggested by a reader. We now also have the capability to provide a key word index to each Digest issue as well as to provide Cyrillic (Russian alphabet) renderings of article, book, author, and/or journal names. We will consider including these features if readers so request. The Index of Digest issues 15-20 should be distributed shortly. Delays for both documents have been occasioned by the switch to our new system.

Of particular interest in this issue are abstracts of a number of chapters from a new Soviet monograph (see *Developmental Biology*: M143) concerning the effects of exposure of space flight on pregnant rats and their offspring. These abstracts appear as *Developmental Biology* P972, P74; *Musculoskeletal Systems* P977; *Psychology* P975, P978, P979; *Reproductive System* P973. Other abstracts presenting or discussing space flight data are: *Cardiovascular and Respiratory Systems* P950; *Hematology* P951; *Life Support Systems* P981; *Neurophysiology* P966.

Soviet Blood Pressure Terms: It has been suggested to us that an explanation of the various blood pressure measurements used by Soviet physiologists would be useful, since the terms may be literally rendered without explanation in some translations of Soviet space biology and related work. The information presented here was extracted from a three-volume Russian medical encyclopedic dictionary published in 1984 by the Soviet Encyclopedia publishing house and edited by B.V. Petrovskiy. First, the usual Soviet term for blood pressure is "arterial pressure." Other terms are:

Basal arterial pressure: blood pressure measured with a cuff immediately upon awakening in the morning, in a fasting patient lying on his back.

Side or lateral arterial pressure: true systolic pressure.

Additional or supplementary arterial pressure: increase in pressure over basal or residual pressure in response to some specified environmental conditions or provocative test, an indicator of hypo- or hypertensive response.

Maximal arterial pressure: systolic blood pressure.

Minimal arterial pressure: diastolic blood pressure.

Residual arterial pressure: difference between random and basal blood pressure, and indicator of blood pressure lability.

Pulse arterial pressure: difference between systolic and diastolic pressure.

Random or accidental arterial pressure: blood pressure measured at an arbitrarily selected time of day without any specific loadings or provocative tests.

Mean or average arterial pressure: level of blood pressure corresponding to the air pressure in the elastic cuff of a tonometer at which during diastole the lumen of the vessel remains closed for the minimal amount of time (as determined using arterial oscillography or analysis of a tachyoscillogram); an indicator of the elasticity of the arterial wall.

Stroke arterial pressure: the difference between systolic and true systolic pressure.

For readers who would like to attempt to make contact with Soviet counterparts, we are providing the addresses of the journal *Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina* [Космическая Биология и Авиакосмическая Медицина, Space Biology and Aerospace Medicine]. Note that the sequence of information in a Soviet address is inverted with respect to ours.

СССР

1179, ГСП-7. Москва

Научный проезд; 6. издательство "Медицина"

Космическая Биология и Авиакосмическая Медицина

Space Biology and Aerospace Medicine

"Meditsina" Publishing House

6 Nauchnyy Proyezd

1179, GSP-7, Moscow

USSR

ADAPTATION

(See also: Habitability and Environment Effects P960; Musculoskeletal System P954; Neurophysiology P966; Psychology P963)

PAPER:

P969(21/89) Chernyayev AL, Muratov NF.

Serum myoglobin in human blood under extreme conditions.

Fiziologiya cheloveka.

14(5): 871-873; 1988.

(14 references; 6 in English)

Authors' affiliation: Institute of Human Morphology, U.S.S.R. Academy of Medicine.

Hematology, Musculoskeletal System, Myoglobin
Humans

Adaptation, Cold, Hypoxia, Psychology, Stress, Far North

Abstract: Fasting blood serum was taken from 63 males, aged 19-50, residents of a city in the Far North. The subjects were divided into 4 groups on the basis of the length of their residency in the North. Group I (n=15) had been in Siberia for 1-10 years; Group II (n=13) for 10-15 years; Group III (N=13) for more than 15 years; while group IV (n=22) had been born in the city. A control group of men of the same ages from Moscow was used. A total of 3 ml serum was taken from each subject and frozen immediately at -20°C . Radioimmune assay was performed on a gammacounter. The mean values and distributions of serum myoglobins were computed for each group.

Level of myoglobins was higher in all groups from the North than in the Moscow subjects. The highest values were seen in residents of the North for 10 years or less and for natives. There was a tendency for level of myoglobin to decrease as length of residency increased. The authors conclude that when humans adapt to the extreme conditions of the Far North, concentration of serum myoglobins increases compared with that of residents of moderate regions. This is particularly true during the first 10 years of Northern residence. The effect is attributed to increased membrane permeability to myocytes, and reflects intensified synthesis of myoglobins in muscle tissue. Serum myoglobins may serve as a marker of adaptation of the human muscle system to cold, hypoxia, and stress.

Table: Concentrations of serum myoglobin in residents of Moscow (C) and Magadan (I-IV)

Group	Myoglobin, ng/ml
C	42.4 ± 5.0
I	154.9 ± 14.4
II	91.9 ± 9.8
III	85.7 ± 6.9
IV	152.0 ± 16.0

Figure: Distribution of blood donors in various groups according to levels of serum myoglobins

BOOK REVIEW:

BR15(21/89)* Grimak LP, Zorile VI.

Review of: Furduy FI.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 93-94; 1988.

Fiziologolicheskiye mekhanizmy stressa i adaptatsii pri ostrom deystvii stress-faktorov

Physiological mechanisms of stress and adaptation in acute exposure to stress factors.

Kishinev: Shtiints; 1986; 240 pages.

KEY WORDS: Adaptation, Psychology, Stress, Biological Rhythms, Endocrinology, Thyroid, Corticosterone, Developmental Biology

Review: Recently the problem of stress and adaptation has been justifiably attracting attention. For this reason, the publication of this monograph by F. I. Furduy, who has repeatedly organized symposia in our country on stress and adaptation and who is a leading expert in this area, was an event of considerable importance to Soviet psychophysiology.

This book summarizes and draws conclusions from data concerning the physiological mechanisms of stress and adaptation. Although more than 11,000 works have been published on this subject in the Soviet Union alone, this is the first monograph that deals with the problem as a whole. It presents a relatively in-depth discussion of systemic mechanisms and general principles underlying the general response of the organism to acute stress, and considers methods to prevent the negative consequences of stress and ways to increase adaptive capacities. Considering that many researchers in the areas of medicine, education, and veterinary science are to some degree concerned with the answers to these questions, the significance of this type of fundamental research is clear.

The monograph consists of six chapters and a conclusion. The first chapter critically examines the current status of the concepts of homeostasis, stress, and adaptation, and presents a detailed analysis of the work of the Soviet scientists P.K. Anokhin, N.A. Agadzhanyan, O.G. Gazenko, P.D. Gorizontov, G. N. Kassil', G.N. Kryzhanovskiy, F. Z. Meyerson, M. I. Mityushov, K.V. Sudakov, V. G. Shalyapina and others, who made substantial contributions to the solution of these problems. At the same time, the author remarks that there has been some delay in our research on the mechanisms underlying the development of stress and adaptation to acute effects of stress factors. This delay has impeded the development of effective measures to prevent the harmful consequences of stress, an issue of the greatest practical importance.

In the second chapter the author analyzes one of the less-studied phenomena of medical chronobiology — hormonal rhythms in stress and their effects on the appearance of the stress reactions. The author has obtained new data relating diurnal rhythms in the concentration of corticosterone in animals to varying degrees of stress-reactivity. Kosinor?? analysis has shown that the acrophase in rats with high reactivity to stress occurs at 0900-1100, while in those with moderate reactivity it occurs at 1400-1600, and at 2000-2200 in those with low stress reactivity. The minimal concentration of the hormone in rats with moderate and especially low sensitivity is observed at 0500-0700, as well as 2000-2200. It has been established that acute stress has a different effect on the development of a response during various periods of the day in animals with varying reactivity to stress: in animals with high stress reactivity the stress reaction is most pronounced at 0500-0700 and 2000-2200, and in those with low reactivity at 2000-2200. Data are cited which demonstrate that the adaptive capacities of animals varying in reactivity to stress are not the same at various periods of the day and depend strongly on the nature and intensity of the stress-factor.

No less important are the characteristics of the establishment of the stress response in early ontogenesis. Based on the experimental data cited, the author demonstrates that responses to different stress factors are formed heterochronologically. The establishment of a stress response is, first and foremost, a function of the stress factors to which the newborn has had to adapt in early postnatal ontogenesis. Also of great practical interest is data showing that exposure to short-term acute stress and specially tailored ecological conditions during an animal's early postnatal development can increase basal level of corticosterone in the blood and simultaneously increase the intensity of the stress reaction and of adaptive capacities in adulthood.

Chapter 3 discusses the role of the thyroid gland in the development of the stress reaction and adaptive capacities. According to one of the leading Soviet experts on the area of stress, member of the U.S.S.R. Academy of Medicine P. D. Gorizontov (1981), the role of the thyroid gland is still debatable. For this reason relevant data are particularly interesting. Scientific facts attesting to the important, and in some cases critical, role of the thyroid in the stress response and adaptation are fundamentally important if we are to find ways to influence this response and its consequences. It is shown that at the beginning of exposure to acute stress, the thyroid gland reacts nonspecifically for a short time — secreting hormones T3 and T4 into the blood, while subsequent changes in the functions of this gland depend on the nature and characteristics of the particular stress factors.

Chapter 4 analyzes the role of various physiological systems: cholinergic, sympathetic-adrenal, hypothalamic-pituitary-adrenal cortex, pituitary-thyroid, and hypothalamic-pituitary-neurosecretory —in the development of stress and adaptation. The author argues that during the initial period of acute exposure to stress factors, the cholinergic system serves as a trigger in the development of stress, while the sympathetic-adrenal system facilitates adaptation. In the early stages of exposure to acute stress, the hypothalamic-pituitary-adrenal cortex system, like the hypothalamic-pituitary-neurosecretor system, supports the development of the stress component of an integrated response. It has been established that the contributions made by various physiological systems to the development of stress and formation of adaptive reactions to it differ at various stages of response formation and depend on the nature and characteristics of the stress factor as well as on the ambient ecological conditions.

Methods for increasing resistance to stress and adaptive capacities in animals, important for medical and veterinary practice, are discussed in Chapter 5. The author critically analyzes the advantages and disadvantages of methods already in use, and proposes new methods that he and his colleagues have developed.

In Chapter 6, F.I. Furduduy examines, on the basis of his own data, the specific physiological mechanisms underlying the development of stress and adaptation. In particular, the author proposes a reexamination of the stress phases proposed by Sel'ye, concluding that only the organism's initial reaction, which Sel'ye called the alarm reaction, should be considered a state of stress. He cites rather persuasive arguments supporting his view that it is only during this period that nonspecific reactions predominate. What Sel'ye calls the resistance period, in which stress reactions are manifested weakly, F.I. Furduduy attributes to homeostatic or adaptive reactions, that serve to support high resistance of the organism. Sel'ye's "exhaustion stage" is considered a pathological reaction of the organism, since functional disruption predominates in the overall response.

In the concluding portion of the book, the author presents the major theoretical points about the role of such factors as the geno- and phenotype, the major endocrinological complexes and physiological systems, diurnal and age parameters, and ecological conditions in which the stress factors operate in the establishment and development of stress and adaptive reactions.

ADAPTATION

Emphasizing the difference in the mechanisms responsible for the overall response to acute exposure to stress factors and chronic exposure to stress factors of moderate intensity, F. I. Furduy shows that in the initial phase of acute stress there is sequential activation of a large number of functional systems and sharp intensification of their activity. These reactions determine the stress component of the reaction. In chronic exposure to a moderate stress factor, one observes primarily an enhancement of functional activity of specific systems fostering the domination of the adaptive component of the overall response.

The issues covered in the monograph have great significance to the problem of stress and adaptation, and to the solution of many practical problems in modern medicine and biology.

The monograph is illustrated with original figures and tables. In conclusion, we can say confidently that this is a significant work that will have substantial influence on the future of research on this problem and on the use of scientific facts for practical purposes.

BIOLOGICAL RHYTHMS: See Adaptation BR15

BODY FLUIDS

(See also: Cardiovascular and Respiratory Systems P964; Developmental Biology M143; Operational Medicine P965)

PAPER:

P961(21/89)* Genin AM, Lakota NG, Chikov LI, Shashkov VS.

A new variant for modeling the effects of weightlessness on humans.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 80-85; 1988.

[24 references; 12 in English]

Body Fluids, Fluid-Electrolyte Metabolism; Neurophysiology, Vestibular Tolerance;
Endocrinology; Human Performance; Cardiovascular and Respiratory Systems
Humans
Immersion, Dry, Suit, Horizontal and Vertical Positions

Abstract: This paper describes the testing of a new "dry" immersion model, which has subjects wear a light waterproof suit. Unlike the old model, in which the subject lies on a waterproof sheet, this model allows the subjects to retain mobility, enabling provocative tests to be administered, and providing closer comparability to conditions under weightlessness. Three tests of this method were performed. All involved an immersion stand with a tub 3.6 x 2.25 m accommodating 1 to 4 subjects. Water temperature was maintained at a comfortable level (not specified) and water purity was kept at a high level. Subjects were a total of 26 healthy males, aged 22 to 47, divided into 2 subgroups (exceptional and average) on the basis of their tolerance of a standard vestibular test. In the first test, 10 subjects were subjected to 6 hours of immersion wearing several different waterproof suits that varied in the depth of immersion they permitted, waterproofing characteristics, comfort, convenience of use of sensors and electrodes while worn, and ease with which orientation was maintained. During the test sublingual body temperature, heart rate, and respiration parameters were measured, and the subjects rated their own general state and the comfort of the suit. The second test was devoted to selection of the optimal temperature regimen and study of the effects of subjects' position (horizontal vs vertical) on the response of the respiratory and circulatory systems. A total of 10 individuals participated in 22 3-hour tests. Core temperature was measured rectally and skin temperature recorded at 5 points; the status of the cardiorespiratory system, distribution of body fluids, and parameters of fluid-electrolyte metabolism were studied. In the third test, 6 subjects spent 2 3-day periods in immersion, once in vertical and once in a horizontal position. Experimenters researched the physiological effects of this treatment on circulation, vestibulomotor reactions, hydration, and hormone parameters.

During the initial few hours of suit immersion, subjects displayed marked hyperemia and edema of the face, hoarseness and stuffy nose, and in some cases difficulty with articulation and abdominal discomfort. Breathing was somewhat impeded, muscles were weak, and vestibular discomfort arose. In the first test it was shown that the most desirable suit is the one developed for cosmonauts in the event of a water landing. This is a light suit with an inflatable headrest that facilitates orientation and movement and minimizes the air pocket under the suit. The suit is worn over warm, desalinized underwear. Special plastic foam floats were used to keep the hands free but dry, and a special headrest was used for sleeping in the vertical position. Special procedures were developed for recording physiological parameters using belts and electrodes with a common cable emerging from the collar of the suit, and for catheterizing the ulnar vein.

BODY FLUIDS

In the second test, subjects found that a water temperature of 25°C was difficult to endure; temperature of 35°C was much more comfortable, but led to orthostatic intolerance after emergence. Optimal temperature was $31 \pm 0.5^\circ\text{C}$. Diuresis, and blood concentration and excretion of osmotically active substances were considerably different under the different temperature regimens. Reliable differences were also found in the circulation, electrolyte balance, and hormonal status of subjects immersed in horizontal and vertical positions. Subjects immersed in vertical position had complaints similar to those occurring under lower body negative pressure (difficulty inhaling, discomfort in the chest cage, and heaviness in the infraclavicular fossa). Unspecified differences in fluid electrolyte balance and hormonal concentrations were also mentioned. During the initial hours of immersion, the vestibuloautonomic syndrome arose, increasing with movement and opening and closing of the eyes. Severity of symptoms was not correlated with tolerance of standard vestibular tests. Spatial illusions also occurred, including total loss of orientation for short periods of times. Subjects fell into two classes, according to their symptoms. The first adapted fairly quickly but avoided sharp movements. The other showed increased vestibular discomfort accompanied by headaches, nausea, and dizziness. Subjects repeatedly participating in immersion sessions showed a marked training effect.

In the third test, involving 3 days of immersion under thermoneutral conditions, initial water loss was greater in the vertical position, but by the end of the period fluid balance was virtually identical in the two conditions. Body weight loss constituted 2-2.5% of baseline, and heart rate, blood pressure and temperature remained within the physiological norm. However, at the end of the period, body temperature had decreased by a mean of 0.6°C , while at the beginning of immersion heart rate increased by a mean of 18-10[sic.] beats per minute in both positions. After immersion, tolerance of passive orthostatic tilt tests worsened, and mechanisms of postural regulation showed signs of disruption. Tolerance of progressive Coriolis acceleration did not decrease in either subgroup after immersion. General physical work capacity decreased in all subjects, but was most affected in those showing most severe vestibular autonomic symptoms during treatment. At submaximal (exercise) loadings all subjects showed significantly diminished maximal oxygen consumption and oxygen pulse after immersion. These changes were least pronounced in the subjects with least discomfort during immersion. The authors conclude that the chief advantage of this suit immersion model is the capacity to unload the antigravity system without requiring hypokinesia per se. While undergoing suit immersion subjects can exercise, perform stipulated movements, and be exposed to vestibular stimulation, which is not possible under the old sheet immersion model.

Table: General state of subjects during 3 days of water immersion to the level of the neck while wearing waterproof suits with an inflatable collar in horizontal and vertical positions

BOTANY: See Life Support Systems P981

CARDIOVASCULAR AND RESPIRATORY SYSTEMS

(See also: Body Fluids P691; Developmental Biology M143, Habitability and Environment Effects P959, Neurophysiology P966, P868; Operational Medicine P965)

PAPERS:

P945(21/89)* Voloshin VG, Bykova Yul, Kuznetsov VG, Lapshina NA.

The physiological effects of acceleration on aerobatic pilots performing aerobatic maneuvers.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 14-17; 1988.

[7 references; none in English]

Cardiovascular and Respiratory Systems, Cerebral Blood Supply

Humans, Pilots

Aerobatic Maneuvers, Acceleration, + and - G_z

Abstract: To obtain background information for this study, 85 aerobatic pilots varying in skill and experience were asked to fill out an anonymous questionnaire. During the aerobatic flights of 25 U.S.S.R aerobatic team members, aircraft acceleration was recorded simultaneously with physiological parameters. A pulsed photoplethysmogram of the ear recorded blood supply to the basin of cerebral arteries. In some flights a continuous EKG was recorded using D-S leads. Baseline physiological parameters were obtained 2-3 minutes before take-off and the same interval after landing. Pre- and postflight blood pressure was measured in the brachial artery and an EKG and correlational rhythmocardiogram recorded.

The questionnaires revealed that 35% of the pilots responding had experienced grayouts and redouts under exposure to positive (about $8G_z$) and negative (about $4 G_z$) acceleration. The majority virtually always experienced grayout during a shift from negative to positive acceleration. Acceleration tolerance worsened under conditions of high temperature and fatigue. Pilots resorted to breath holding, clenching of abdominal muscles, and use of tight straps to improve tolerance. Heart rate averaged 100-110 beats per minute during flight, reaching a maximum of 160 during positive acceleration; during negative acceleration heart rate decreased to 60. The greatest effects on heart rate occurred when high positive and negative acceleration alternated rapidly. In such cases, heart rate could change by approximately 50% in 1-2 seconds. These changes in heart rate when acceleration shifts direction are attributed to the responses of regulatory mechanisms in higher processing centers to fluid shifts.

Pulsed oscillations, as indicated by the pulsed photoplethysmogram, virtually ceased during high levels of acceleration or rapid alternation between lower levels of positive and negative acceleration. Extrasystoles occurred in some pilots during or immediately after acceleration. No rhythm disruptions were noted postflight. Correlational rhythmography revealed the phenomenon of "rigid pulse" (no variation in R-R intervals). The authors conclude that aerobatic maneuvers demand a high level of fitness on the part of the pilots, especially with regard to the cardiovascular system.

Figure 1: Sample of flight recording of an accelerogram and pulsed photoplethysmography

Figure 2: Heart rate dynamics during flight with acceleration

Figure 3: Disruption of cardiac rhythm recorded on a pulsed photoplethysmogram in horizontal flight after acceleration

P950(21/89)* Krotov VP, Sandler G. Magedov VS, Heinz J, Badakva AM, Nazin AN (U.S.S.R, U.S.A).

Hemodynamics in monkeys during early adaptation to microgravity,

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 33-39; 1988.

[10 references; none in English]

Cardiovascular and Respiratory Systems, Hemodynamics

Monkeys, Individual Differences

Space Flight, COSMOS-1514, -1667

Abstract: This experiment investigated whether the lack of coordination observed in the circulation parameters of a monkey flown on COSMOS-1514 is characteristic of all monkeys during early adaptation to weightlessness or was simply a peculiarity of the individual. Six *Macaca mullatta*, monkeys, 3.5-4.5 years old, were flown on COSMOS-1667 in the "Bio-Primat" capsule. Blood pressure and linear circulation rate were measured using preimplanted electrodes and transducers in the left carotid artery. (Apparatus developed at Ames Research Center.) The implantation operation was conducted in 2 stages: in the first stage, the transducers were implanted and their wires passed subcutaneously to the animals' backs; after 3-4 weeks, the wires were extruded from the skin and electrodes implanted for recording EKG through tetrapolar chest leads and measuring minute circulatory volume through impedance plethysmography. The investigation started 2-3 weeks after the second stage of the operation.

Individual differences in regulation of circulation began to be detectable 2-3 weeks after the second stage of the operation, while the monkeys were housed for a period of 3 days in Bio-Primat capsules in a mock-up of the biosatellite, in response to provocative tests of postural effects. Selection of flight candidates was based on the results of the preflight examinations. The state of the circulatory system in flight was studied in the monkey called Gordyy. Data from the same animal 1 month after flight while housed for 7 days in a mock-up were used as control data. State of hemodynamics during 7 days of confinement in the Bios-Primat capsule within a satellite mock-up was studied in two additional monkeys. Signals were recorded on magnetic tape during 5-minute sessions every 2 hours during the day and every half hour at night. Data analysis procedures are cited but not described.

During the 3-day period that Gordyy was being familiarized with the satellite mock-up, blood flow decreased in the common carotid artery. Stabilization after day 2 indicates adaptation to the unfamiliar and confined surroundings. During the animal's first 30 minutes of exposure to weightlessness, his linear circulation rate increased from 33.4 (during prelaunch period) to 44.6 cm/sec. It subsequently decreased, but remained above baseline. On day 1 of flight, linear circulation rate was a mean of 38.7 cm/sec during the day and 40.0 cm/sec. at night. But a day later, the mean values were only 3-9% above baseline, remaining at this level for the next 4 days. Over the course of 24 hours in space, linear circulation rate followed a pattern of decreasing in the early evening (1600-1800) and increasing during the night, reaching a maximum at 2000. During the postflight control experiment, blood flow rate decreased in the early evening and increased at night, but remained 20-25% higher than during the preflight control experiment.

The blood pressure sensor responded to barometric pressure as well as blood pressure. Because the apparatus recording hour-to-hour cabin pressure malfunctioned, subtle changes in blood pressure could not be detected. During the initial period of flight, hypo- and hypertensive reactions were absent, and the difference between two successive measurements did not exceed 10 mm. Over the 6-day flight, blood pressure tended to rise (by a total of 15 mm HG by the end of the flight). Mean blood pressure, however, did not tend to increase in the postflight control experiment with the same animal. Regional peripheral resistance decreased during the first

CARDIOVASCULAR AND RESPIRATORY SYSTEMS

hours of exposure to space. Subsequently it increased during the first 4 days of flight, and then stabilized. No analogous pattern was noted in the postflight control experiment.

The ratio of linear circulation rate to minute circulatory volume reflects the proportion of the total blood in the body supplied to the brain. Clear diurnal variations in this ratio are interpreted by the authors as indicating good adaptive capacity. However, while on the ground the maximum and minimum values occur at the same time of day (2200 and 1600, respectively), there was considerable variation in the corresponding times in space.

No signs of desynchronosis were observed when two animals were confined in a Bios-Primat capsule on the ground. Facial edema observed on the television screen did not appear to be associated with linear blood flow or blood supply to the head.

The changes observed in Gordyy were very different from those seen in the monkey Bion, flown on COSMOS-1514. During the early stages of flight, Bion's blood pressure increased, linear blood flow rate decreased, and regional peripheral resistance increased. On days 2 and 3 of flight, the same animal showed decreased diurnal periodicity in linear blood flow rate, regional peripheral resistance, and ratio of blood flow rate to minute volume, normalizing only on day 5. Such major changes in diurnal patterns did not occur in Gordyy.

The differences between the responses of Gordyy and Bion lead the authors to doubt the primacy of fluid shifts in the response of the circulatory system to space. Instead, they believe that these changes result from lack of coordination between various functional systems, caused both by fluid shifts and changes in afferent stimulation. The differences in the two monkeys in the parameters discussed were also manifest in obvious differences in their general state in space (e.g., motor activity, appetite).

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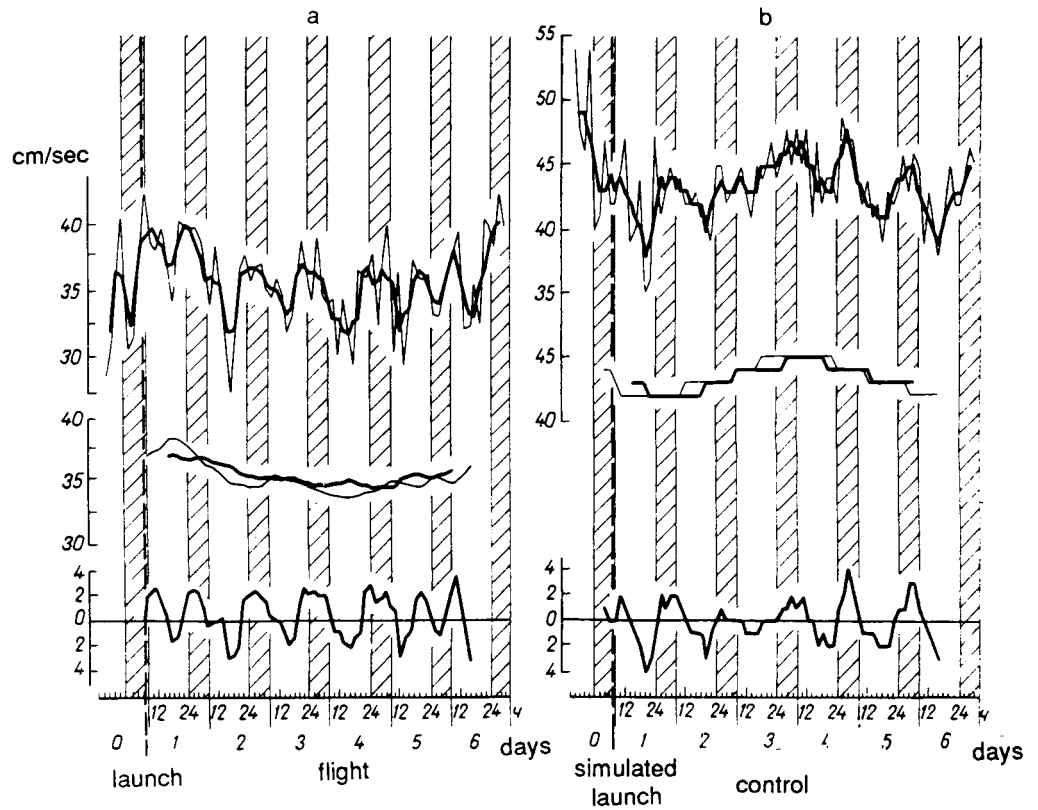


Figure 1: Changes in linear blood flow rate and its diurnal periodicity in the monkey Gordyy in flight (a) and in a control condition (b).

Abscissa — time, hours and days; ordinate — linear blood flow rate in cm/sec.

Upper graph — measurement data obtained during initial data processing (thin line) and after symmetrical smoothing using three points (thick line).

Middle graph — same data after symmetrical smoothing using 12 points (thin line) and 23 points (thick line);

Lower graph — diurnal periodicity. Hatched areas correspond to the night sleep period

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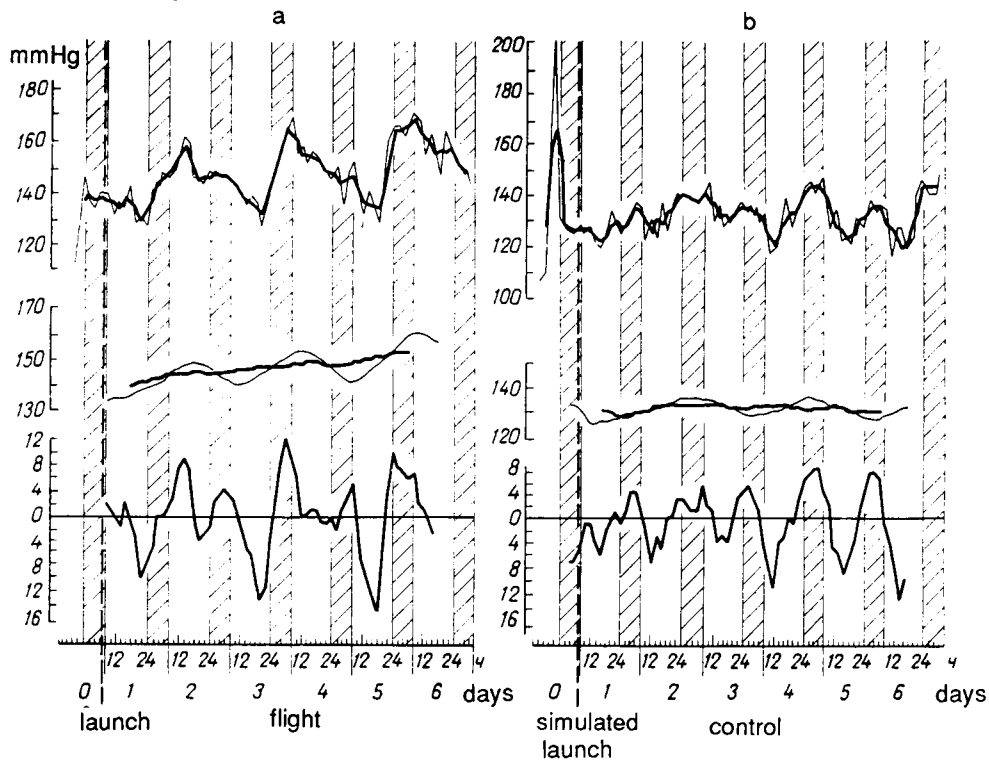


Figure 2: Changes in blood pressure and its diurnal periodicity in the monkey Gordyy in flight (a) and under control conditions (b).

Abscissa — time scale: hours and days — blood pressure in mm Hg. Key: as in figure 1.

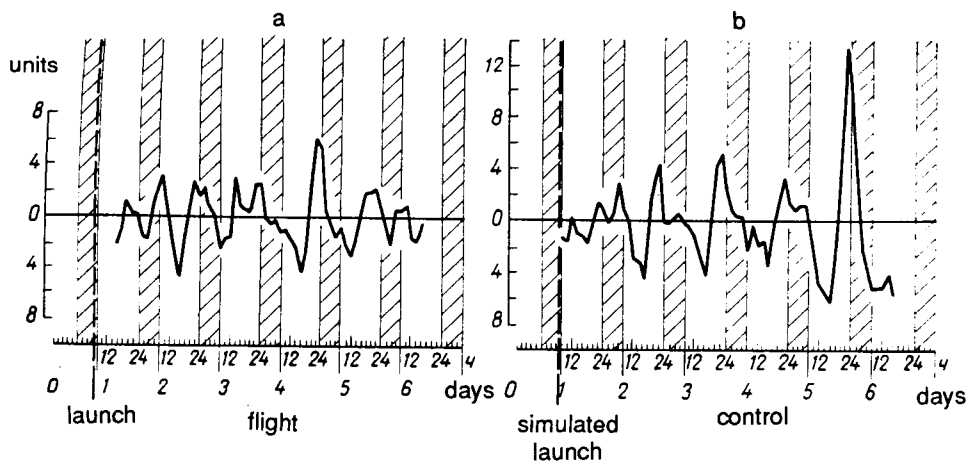


Figure 3: Diurnal periodicity of the ratio of blood flow to the head and minute circulatory volume in the monkey Gordyy in flight (a) and in a control condition (b).

P952(21/89)* Vorob'yev VYe, Kovachevich IV, Goncharov IB, Vinnitskiy LI, Yegorova IA, Kal'yanova VN.

Changes in regional pulmonary hemodynamics and level of vasoactive substances in humans exposed to hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 42-46; 1988.

[13 references; none in English]

Cardiovascular and Respiratory Systems, Pulmonary Hemodynamics, Vascular Tonus;
Enzymology, Renin, Angiotensin, Kinin-Kallikrein
Humans, Males
Hypokinesia with Head-down Tilt

Abstract: The goal of this experiment was to study the state of regional pulmonary hemodynamics and investigate activity of the renin-angiotensin and kinin-kallikrein systems, which participate in the regulation of vascular tonus, under exposure to hypokinesia with head-down tilt. Nine apparently healthy males were subjected to -8° hypokinesia with head-down tilt for 14 days. Subjects were studied during a baseline period and on days 3, 10, and 14 of treatment. Zonal rheography (impedance plethysmography) of the upper, middle and lower portions of the lungs was performed. The following parameters were computed: a rheographic index reflecting the state of pulsed perfusion of the vessels in the areas studied; the α/T ratio, indicating state of tonus and elasticity of high and moderate caliber vessels; the dichrotic index and the diastolic index, both of which provide information about the tonus of arterioles and small arteries, venules and veins, i.e., pre- and postcapillary resistance. Concentration of renin in blood plasma was determined using radioimmunological assay. Activity of the kinin-kallikrein system was studied by determining the level of prekallikrein and kallikrein inhibitor in blood. Subjects were at rest for all measurements. Student's t-ratios were used.

Impedance plethysmography revealed fluid shifts in the apical direction in all subjects as early as day 3 of treatment, probably due to decreased postcapillary resistance in the upper and middle zones, leading to increased venous hyperemia, as well as to increased postcapillary tonus in the lower pulmonary region. There was also a significant increase in tonus of arterial vessels in the upper and middle pulmonary areas and in precapillary resistance in the pulmonary circulation tract, evidently a compensatory response stabilizing perfusion and preventing excess blood in the lungs. By day 3, there was generalized reduction in pulsed blood perfusion due to pre- and postcapillary vascular resistance, which progressively increased throughout the hypokinesia period. Tonus of pulmonary vessels changed in different directions at different times during the treatment. Throughout treatment there was a significant increase in blood renin, suggesting activation of the renin-angiotensin system as a whole. Renin plays a key role in the formation of angiotensin from which the vasoactive peptide angiotensin II is synthesized. The latter can narrow the vessels of the circulatory tract by stimulating adrenergic receptors. In this study, there was some parallel between renin concentrations and rheographic parameters providing information about the vessels in the lungs. Prekallikrein and kallikrein inhibitor did not change significantly during hypokinesia, but may become important after longer periods. The authors conclude that basal-apical redistribution of the regional functions of the lungs occurs under conditions of hypokinesia with head-down tilt, but does not provide an adequate degree of ventilatory homeostasis.

Table 1: Changes in parameters of a rheopulmogram in subjects exposed to hypokinesia with head-down tilt

Table 2: Changes in concentration of renin, activity of the kallikrein-kinin system, prekallikrein and kallikrein inhibitor under conditions of hypokinesia with head-down tilt

CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P956(21/89)* Artemyan NA., Barinyan SB, Oganessian SS, Shperling ID.
Ultrastructural analysis of atrial cardiomyocytes in rats exposed to acceleration of +5G_z.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 60-64; 1988.

[20 references; 7 in English]

Cardiovascular and Respiratory Systems, Atrial Cardiomyocytes

Rats

Acceleration, +5G_z

Abstract: Subjects were 7 white outbred rats; a control group of 7 animals was also used. Subjects were centrifuged for 25 minutes every day for 15 days with acceleration of +5G_z. Three animals (adapted group) were sacrificed 1 day after this period, and 4 more (readapted group) after a 30-day readaptation period. Portions of the auricles of the left and right atria were removed, fixed, dehydrated in ethanol, and poured into a mixture of epon and araldite. Ultrafine sections were obtained, contrast-stained twice, then examined with an electron microscope.

Both the left and right auricles of adapted animals showed cardiomyocyte changes. There were indications of activation of the nucleolar apparatus manifested by invagination of the nuclear membrane and an increase in the number of nucleoli. Large Golgi complexes were seen near the nucleus, frequently accompanied by specific auricular granules filled with dense substance. Some of these had a fine honeycomb structure. These granules could frequently be observed forming from Golgi complexes. Destructive changes (e.g., decreased glycogenesis in cytoplasm, relaxed myofibrillar sarcomeres, dissolved filaments of the I-disc, homogenized matrix, lysis of cristae, and presence of dense granules in the mitochondria, widening intercalated disks) were also noted in cardiac myocytes in some cases. After 20 days of readaptation, the severity of the hypertrophic process in individual cells and the number of such cells decreased. The Golgi complex near the nucleus consisted most frequently of a small number of short lamellae and fine vesicles; there were only isolated dense specific auricular granules, which were of medium size, with lowered density. The number of cardiomyocytes with destructive changes increased in this group.

The authors conclude that there are two general ways in which long-term acceleration affects cardiomyocytes: various degrees of hypertrophy and hyperplasia of organelles on one hand; and destructive changes on the other. Many of the changes are similar to those observed in response to hypoxia and ischemic heart disease. Thirty days of readaptation did not lead to increased regeneration or complete normalization. Instead, the number of cells affected by destructive changes increased, as did destruction of subcellular structures, especially myofibrils. These changes evidently occur in hyperplasmic organelles. The authors suggest that a factor produced by the specific auricular granules, which has a wide range of effects on the cardiovascular system and kidneys, plays a role in these changes.

Figure 1: Thick bundle of myofibrils with the beginning of longitudinal cleavage

Figure 2: Accumulation of specific auricular granules near a Golgi complex

Figure 3: Lysis of myofibrils among intact mitochondria and elements of the sarcoplasmic reticulum

Figure 4: Destruction of specific auricular granules near a Golgi complex

P957(21/89)* Lobanok LM, Kiriyeiko AY.

Age differences in adrenergic regulation of the contractile function of the heart under conditions of hypoxia.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 64-68; 1988.

[12 references; 5 in English]

Cardiovascular and Respiratory System, Contractile Function; Endocrinology, Adrenergic Regulation

Rats, Age Differences

Hypoxia

Abstract: This study investigated age differences in how hypoxia affects peripheral adrenergic regulation of biomechanical cardiac functions. Subjects were 109 white male rats of two age groups: 8-10 months (mature) and 24-26 months (old). The heart was removed from anesthetized animals and placed in a thermostatic chamber. A peristaltic pump was used to perfuse the isolated heart with Krebs-Henseleit solution, at constant pressure in the aorta of 60 mm Hg and a speed of 12 ml/min. Oxygen pressure was 600 mm Hg and carbon dioxide pressure was 30 mm Hg. Solution acidity was maintained at pH 7.40. The electric activity of the curve of intraventricular pressure and its first derivative were recorded using a biopotential amplifier, biomonitor, and recorder. A hypoxic solution ($pO_2 = 100$ mm Hg) was created by removing oxygen with nitrogen. Alpha-adrenergic receptors were stimulated with mesaton in concentrations of $5 \cdot 10^{-7}$ - $10^{-5}M$ while beta-receptors were blocked with obzidan. Beta-adrenoreceptors were stimulated with isoprenalin (10^{-9} - $10^{-6}M$) while alpha receptors were blocked with phentolamine. The following parameters were analyzed: heart rate, systolic and diastolic pressure in the left ventricle, rate of increase and decrease of systolic pressure, contraction and semirelaxation periods, contractility and relaxation indexes, and circulatory minute volume.

Results confirm that the inotropic and chronotropic response to alpha-adrenergic stimulation increases with age. Mesaton in an oxygenated solution decreased heart rate by 11.7% and increased systolic blood pressure, and rate of its increase and decrease by 7.8, 14, and 17.6%, respectively in mature rats; the corresponding changes were -15.3%, + 21, +26.6, and +37%, respectively, in old rats. When hypoxia was created in the solution, the reactions to the alpha-adrenergic agonist changed. In mature rats, heart rate increased by 11%, while systolic blood pressure and its rate of increase and decrease increased by 29, 31, and 48%, respectively. Myocardial contracture induced by oxygen deficit increased by 39.5% in the presence of mesaton. In the hypoxic medium, mesaton did not alter heart rate or contractility parameters and did not increase contracture of the cardiac muscle in old rats.

Stimulation of the beta-adrenergic receptors with isoprenalin under normoxic conditions induced a greater chrono- and isotropic effect in older animals. The increase in heart rate was 30% greater in older animals' hearts, while the comparable increase in systolic blood pressure was 22.1 greater, and increases in rate of its increase and decrease were 52.5%, and 61.8%, respectively greater in the older hearts. Increase in coronary blood flow rate induced by adrenergic-agonists was 27% higher in the hearts of the older animals. Under conditions of hypoxia, stimulation of beta-adrenoreceptors led to an increase in the chronotropic response of the heart in mature subjects (45%) and a decrease in the response (by 31.8%) in old subjects. Parameters indicative of inotropic function (rate of change in systolic blood pressure, and indices of contractility and relaxation) did not change in mature rats; however, systolic blood pressure increased by 36.9% and diastolic by 31.4%. [original says 314.8%.] In old rats, rate of change in systolic blood pressure increased, but less than under normoxic conditions. Increase in diastolic pressure under the maximum dose of agonist was reduced by 112%. When

CARDIOVASCULAR AND RESPIRATORY SYSTEMS

a current of 5.0 Hz was used to induce rhythm under conditions of beta-adrenergic stimulation, the inotropic effect decreased with the response of the older hearts being greater.

The authors conclude that in a mature animal, hypoxia of the myocardium leads to enhanced functional response of the pacemaker to stimulation of adrenergic receptors. On the other hand, in older animals, oxygen insufficiency attenuates adrenergic control of the chronotropic cardiac function. This difference may be due to decreased numbers of beta two receptors (which play a critical role under exposure to extreme conditions) in older animals. Under conditions of oxygen deficit, the inotropic response of mature animals to stimulation of beta-receptors is lower than that of older animals. This may be due to increased role of glycolysis in supplying energy to the cells of the myocardium in older subjects. Another explanation may be the greater increases in coronary blood flow in the hearts of older individuals both in response to hypoxia and to stimulation of beta-adrenergic receptors.

Figure 1: Changes in heart rate and rate of increase in intraventricular pressure in response to stimulation of alpha-adrenergic receptors in the isolated hearts of mature and old rats under conditions of normal oxygenation and hypoxia.

Figure 2: Change in coronary flow when oxygen pressure is decreased in perfusing solution and stimulation of beta-adrenoreceptors in the isolated heart of mature and old rats

Figure 3: Changes in heart rate and rate of decrease in intraventricular pressure after stimulation of the beta-adrenoreceptors of the isolated hearts of mature and old rats under conditions of normal oxygenation and hypoxia

Figure 4: Effect of hypoxia and stimulation of beta-adrenoreceptors under conditions of hypoxia on diastolic pressure in the isolated hearts of mature and old rats

P962 (21/89)* Palets BL, Popov AA, Tikhonov MA, Kondakov AV, Palets LD.

Calculating the effectiveness of an indirect technique for assessing tolerance of +G_z acceleration using a simulation of circulation.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 85-87; 1988.

[7 references; 3 in English]

Cardiovascular and Respiratory Systems, Circulation

Humans

Acceleration Tolerance, +G_z, LBNP, Mathematical Modelling,

Abstract: This work sought to determine if application of mechanical forces to the veins can affect hemodynamic parameters similarly to gravitational acceleration to the limit of tolerance. If this were the case mechanical effects could be used to indirectly assess tolerance of acceleration. This research used a previously published simulation model of human circulation under different gravitational loadings. The acceleration schedule involved linear increases at a rate of 0.1 g/second in a sitting position (=60°) without antigravity measures or muscle tension. The normal endurance limit was considered to be 5 units, while the cerebral bloodflow corresponding to 4-g was considered the maximum acceptable for people with reduced tolerance. Earlier research had shown that the mathematical model was appropriate for generating data equivalent to responses to passive orthostatic position on a tilt test, and +G_z acceleration with and without use of antigravity suits.

To determine the effectiveness of the indirect technique for evaluating acceleration tolerance data generated for subjects with normal and diminished tolerance of acceleration were compared. Hemodynamic responses to +G_z in subjects with reduced tolerance was simulated in two ways: increased compliance of the veins of the lower body and decreased functional reserves of baroreflex regulation. In both cases, the magnitude of the effect was selected for maximum tolerance of 4 units. The model parameters were revised to reflect these conditions.

Data were generated by the model to correspond to effects of LBNP (increasing to -40 mm Hg at 50 seconds) and +G_z acceleration. In normal subjects, decreased overall blood flow would cause endurance limit to be reached for LBNP, while blood flow to the brain still remained unaffected; in contrast, blood flow to the brain is the limiting factor under exposure to acceleration. When subjects with reduced tolerance were simulated, the schedule of LBNP did not decrease blood flow to the brain to the level corresponding to that occurring during maximal endurable acceleration. At the same time, this treatment led to significant stress on the circulatory regulation. Because of the latter circumstance, tolerance for long periods of LBNP depends directly on the functional reserves of the subjects' cardiovascular system and thus may show some correlation with tolerance of acceleration.

To achieve correspondence between the indirect model and acceleration tolerance, pressure in the carotid sinus and thus blood flow to the brain had to be decreased. This was achieved by modelling increased resistance to blood flow by simulating narrowing of the lumen of vessels supplying blood to the brain. In the subsequent simulation, LBNP (increasing linearly for 50 seconds to various values ranging from 0 to -40 mm Hg) was combined with pinching of the common carotid arteries and veins so that resistance also increased linearly. When normal subjects and those with decreased tolerance were simulated, the effects generated by the model on blood supply to the brain were similar to the model simulations of response of the same parameters to +G_z acceleration.

Figure 1: Reactions of circulatory parameters to linearly increasing +G_z acceleration in a seated and relaxed position

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Figure 2: Reactions of hemodynamics to linearly increasing LBNP, and resistance of the common carotid arteries and jugular veins

Figure 3: Effects of linearly increasing LBNP and resistance on decrease in minute circulatory volume to the brain after 50 seconds of treatment

P964(21/89)* Andriyako LYa, Bubeyev VA, Degtyarev VA, Kaplan MA, Remizov Yul, Gorin VV, *Reactions of the vascular regions of visceral organs to lower body negative pressure.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 90-91; 1988.

[7 references; 2 in English]

Cardiovascular and Respiratory Systems, Vascular Regions, Visceral Organs; Body Fluids,
Fluid Redistribution
Humans, Males
Lower Body Negative Pressure

Abstract: In this experiment, 5 apparently healthy males, aged, 29-40, were exposed to lower body negative pressure (LBNP). Plasma was labelled with ^{93m}Tc -albumin administered intravenously in a dose of MBq/kg. A radiation detector at the level of the chest and abdomen of subjects in horizontal position recorded information every 60 seconds, starting at administration of the radioactive preparation. Ten-15 minutes after the preparation was administered, when it was evenly distributed throughout the body, LBNP was applied without the subjects changing their position. Decompression was apparently applied up to the level of the iliac bone. Decompression schedule consisted of 3 minutes at each of the following negative pressures: 10, 20, 30, 40, 50, and 60 mm Hg. The following regions were observed on a computer display: chest and abdomen area, upper lobe of the lung, liver, heart, large vessels of the mediastinum, portion of the intestine near the navel. Activity-time curves were constructed. Correlational and regression analyses were performed.

The data suggest that blood from the visceral organs and large vessels of the chest cage are actively drawn into the area of decompression. The fastest rate of redistribution occurs in the initial stages of progressively increasing decompression. As decompression increases, rate of redistribution slows. Veins from the organs of the chest are more affected than those of the abdomen. Greatest changes (up to -23%) occurred in the upper lobe of the lung. Half of the redistribution from the upper lobe of the lung occurred when pressure dropped to -10 mm Hg. It required 2-3 times the decompression to achieve this magnitude of fluid volume loss from the vessels of the heart and mediastinum. The vascular net of the splanchnic region, particularly the liver, was less sensitive to LBNP. At pressures of -60 mm Hg, the decrease of blood volume in the liver was one-fifth that in the lungs. Blood volume loss in response to LBNP is different for different organs, which should be considered when this treatment is used as a countermeasure in weightlessness.

Figure: Changes in blood volume in the organs of the chest cage and abdominal cavity in response to LBNP

CYTOLOGY: See Developmental Biology M143

DEVELOPMENTAL BIOLOGY

(See also: Adaptation BR15; Musculoskeletal System P977; P978, P979, Reproductive System P973)

PAPERS:

P972(21/89)Serova LV, Denisova LA, Chel'naya.

Experimental conditions on the COSMOS-1514 biosatellite.

In: M143(21/89) Gazenko O.G. (editor) Ontogenez mlekopitayushchikh v nevesomosti

[Ontogeny of Mammals in Weightlessness]

Moscow: Nauka; 1988. Pages 37-38.

Developmental Biology, Reproductive Biology, Equipment and Instrumentation

Rats, Female

Space Flight, COSMOS-1514

Abstract: This article describes the conditions of an experiment conducted on COSMOS-1514 and using female Wistar line rats approximately 4 months in age and weighing 280-310 g. The animals were prepared for flight in accordance with a special program that included clinical and physiological examination, assessment of estrous cycles, habituation training, and formation of a group to evaluate compatibility.

The female rats of the flight group were impregnated on the ground before the experiment began. The first day of pregnancy was counted as the day that spermatozooids were found in a vaginal smear. The spacecraft was launched at the beginning of day 13 of pregnancy and reentered at the beginning of day 18 of pregnancy.

During the 5-day flight, 10 pregnant female rats were housed in a cell block of the BIOS-Vivaria device (Figure 5), which was 160 X 220 X 660 mm. Each animal received 55 g daily of a special moist feed (94.5 calories per day) and water. The cage was illuminated for 16 hours daily during flight. Air temperatures fluctuated within the range of 20-24°; pO₂ varied with in a range of 159-210 mm Hg with pCO₂ of up to 1.5 mm Hg.

Three groups of control animals were used: a vivarium control group (n= 25); a baseline control (n=30), dissected on the day of launch for evaluation of initial fertility and general state; and a synchronous control group (n=10) housed in a mock-up of the biosatellite and exposed to simulated space flight and reentry conditions.

On the day of reentry, 5 female rats of the flight group were dissected, providing approximately 60 fetuses for the study. The remaining 5 animals were allowed to continue their pregnancy to term and approximately 50 living neonates were obtained from them. These neonates were observed for several months of postnatal life, until they reached sexual maturity. Studies of these neonates are summarized elsewhere in this Digest issue.

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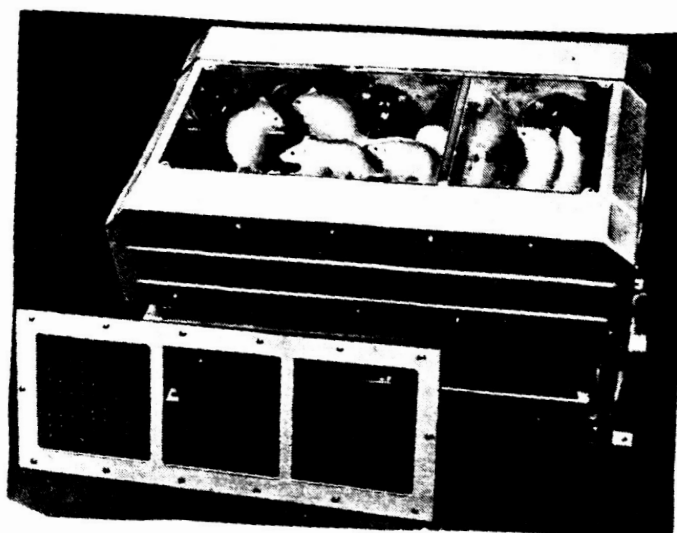


Figure 5. Bios-Vivaria block

P974(21/89) Serova LV(U.S.S.R.), Batsek A(Czechoslovakia), Denisova LA, Lavrova YeA, Makeyeva VF, Natochin YuV, Chel'naya NA, Shakhmatova Yel (U.S.S.R.) .

The state of the neonates.

In: M143(21/89) Gizenko O.G. (editor) Ontogenez mlekopitayushchikh v nevesomosti

[Ontogeny of Mammals in Weightlessness]

Moscow: Nauka; 1988; pages 74-79.

Developmental Biology, General State, Reproductive Biology, Birth Process, Musculoskeletal System, Bones, Body Fluids, Hematology

Rats, Neonates

Space Flight, COSMOS-1514

Abstract: This chapter describes studies of rats born from mothers that had been flown on COSMOS-1514 between days 13-18 of their pregnancies. The flight mothers began to gain weight rapidly as soon as they returned to Earth. While they had gained only 5 g throughout the flight (compared to 65 g in the control), during their first day on Earth they gained 35 g. The birth process was more difficult and prolonged in the flight rats than in control animals. Flight rats showed greater individual differences in the birth process than did the control groups.

The 2 mothers of the flight group that delivered first bore normal litters with 13 neonates in each. Two other rats had prolonged and difficult births and each litter contained one stillborn fetus. In one rat from the flight group, the birth process lasted 2 days, due to general weakness and the presence of one very large fetus (greater than 7 g). Since for a long period the mother was unable to deliver this fetus, which was first in the birth canal, the other fetuses — full-term and normally developed — died from anoxia due to the long delay between the detachment of the placenta and their final emergence from the mother. The authors state that they had never encountered a similar circumstance among more than 1,000 births in their vivarium. The largest neonate rat, which was first in the birth canal, was found to have hydrocephalus and also subdermal edema in the area of the head, which had evidently developed in the course of the birth process. The litters of the 4 flight rats that bore living neonates, averaged 12 rats per litter (3 litters had 13 neonates each, and 1 had 9); mean litter size in the synchronous group was also 12 (from 11 to 14), while the vivarium control group averaged 10 (from 8 to 15).

The body weight of the neonate flight group averaged 5.92 g and was lower than that of the vivarium control (6.48 g), but higher than that of the synchronous control (5.6 g). The total weight of the neonates of a single mother was an average of 71.0 g in the flight group, virtually the same (70.8 g) as the synchronous control, and somewhat greater than that of the vivarium control (65.1 g) due to the greater litter size in the flight animals.

A comparison of these weights with the total weight of the fetuses carried by each female on day 18 of pregnancy showed that during the 5 days of the readaptation period on Earth, the fetuses of the flight group mothers increased their weight by 59.6 g per litter, with the comparable figure for the vivarium control being 53.6 g.

The external appearance of the flight neonates was appropriate to their calendar age. No anomalies were found in their internal organs. The neonate flight and synchronous groups did not display the hemorrhaging observed earlier in fetuses. (See Reproduction: P973, this issue.) This suggests that the hemorrhages were slight and the associated tissue changes were reversible. The ratio of males and females in the litters of the three groups were identical. After birth, the litters were equalized so that each contained 8 neonates in order to create comparable conditions for all the litters during the nursing period. Biochemical and morphological studies were performed on 16 living neonates of the flight group, 11 rats from the synchronous control group and 21 neonate rats from the vivarium control group.

When the skeletons of the neonates were measured it was found that the flight animals displayed an increase in ossification sites by 10-17% compared to the control (Figure 21), while the fetuses of the experimental group had showed delay in skeletal development.

Liver weight of neonate rats was significantly lower than in the control groups, while the concentration of fluid in liver tissue per kilogram dry weight was identical in all three groups. There were no differences among the groups in concentrations of sodium, potassium, or calcium in liver tissue (Table 24). No differences were found among the groups in concentration of DNA, RNA, or protein in liver tissue (Figure 25).

The weight of the myocardium of the neonate rats in the flight group was 29.7 mg higher than in both control groups. No intergroup differences were found in hydration of myocardial tissue or in concentrations of sodium, potassium, or calcium. Kidney weight in the neonates of the flight group averaged 29.2 mg and was higher than that for the synchronous control, but did not differ from the vivarium group. Kidney tissue hydration and concentrations of potassium and calcium were identical in all three groups. Concentration of sodium in kidney tissues of neonate flight rats was below that of the two control groups (Table 24).

Table 26 presents the results of hematological examination of the neonate rats in the flight and control groups. Two to three hours after birth, flight animals showed a reliable decrease in concentrations of hemoglobin and reticulocytes compared to animals of the synchronous and vivarium control groups. There were no intergroup differences in leukocyte levels or in a leukogram of peripheral blood. Concentrations of colony forming units (CFU) in the spleen of neonate flight rats were almost twice as high as in the vivarium and synchronous control groups ($p < 0.001$), while concentration of CFUs in the livers of neonates was identical for the flight and vivarium groups. In the synchronous group, the number of colony forming units was elevated at this point (2-3 hours after birth).

Results of this portion of the experiment show that fetuses spending part of the prenatal period under conditions of weightlessness were able to complete their development on Earth in the acute period of maternal readaptation to normal g. No structural-anatomical anomalies occurred; the animals developed at a normal rate and even compensated for certain changes, e.g., retardation in skeletal development, decrease in hemopoietic stem cells, and bleeding, observed in fetuses immediately after reentry.

DEVELOPMENTAL BIOLOGY

Table 24: Weight and fluid and electrolyte content in organs of newborn rats

Organ	Grp	Weight, mg	H ₂ O, kg/kg dry wt	NA mequiv/kg dry weight	K mequiv/kg dry weight	Ca mequiv/kg dry weight
Kidney	F	29.2±1.6 ps<0.01	6.87±0.18	559.6±12.2 ps<0.01 pv<0.02	578.2±31.6	30.2±4.0
	SC	21.2±0.9	7.4±0.77	635.0±17.7	679.7±34	31.2±7.7
	VC	26.2±0.9	6.88±0.16	615.7±15.8	594.4±10.1	38.7±4.0
Liver	F	255±13 pv<0.001 ps<0.01	3.17±0.12	204.2±24.1	356.5±9.8	12.9±2.8
	SC	322.±12	2.97±0.075	223.9±17.7	350.5±27	8.5±1.02
	VC	329±10	3.1±0.039	188.0±7.7	342.6±8.6	7.2±0.6
Myocardium	F	29.7±1.0 pv,s<0.001	5.04±0.11	355.2±10.5	488.9±12.5	25.1±3.4
	SC	23.8±0.7	4.86±0.066	370.4±15.4	460.6±51.9	--
	VC	24.5±0.7	4.84±0.1	358.7±9.8	494.4±9.1	35.4±4.8

Table 25: Concentration of nucleic acids and protein in the liver of neonate rats

Group	DNA mg/g moist tissue	RNA mg/g moist tissue	Protein, µg/mg moist tissue
Flight	4.3±0.21	16.3±0.8	107±5
Synchronous	3.8±0.18	13.5±0.4	104±6
Vivarium	3.8±0.28	14.1±0.5	118±8

Table 26: Some characteristics of peripheral blood and hemopoietic organs in neonate rats

Peripheral blood							
Grp	1	2	3	4	5	6	7
F	10.56±0.22 pv<0.01 ps<0.05	874±10.5 ps<0.001 pv<0.002	72±2.9	1.9±0.56	3.1±0.58	1.26±0.24	0.44±0.08
SC	11.7±0.29	926±7.6	79±2.8	2.1±1.2	4.4±0.8	1.3±0.28	0.7±0.13
VC	11.4±0.27	931±4.9	79±2.4	1.2±0.17	2.7±0.34	1.2±0.112	0.5±0.043

1. Hemoglobin, g %; 2. Reticulocytes, %; 3. Erythroblasts, %;
 4. Lymphocytes, thousand/mm³; 5. Neutrophils with segmented nuclei,
 thous./mm³; 6. Neutrophils with basilar nuclei,, thous./mm³;
 7. Young neutrophils, thous./mm³.

Table 26 (continued)

Group	CFU (per 10 ⁶ cells)	
	Spleen	Liver
Flight	19.2±0.7	9.5±0.5
	ps,v<0.001	ps<0.001
Synchronous	8.5±0.8	26.0±2.0
		pv<0.001
Vivarium	10.0±0.8	10.3±1.0

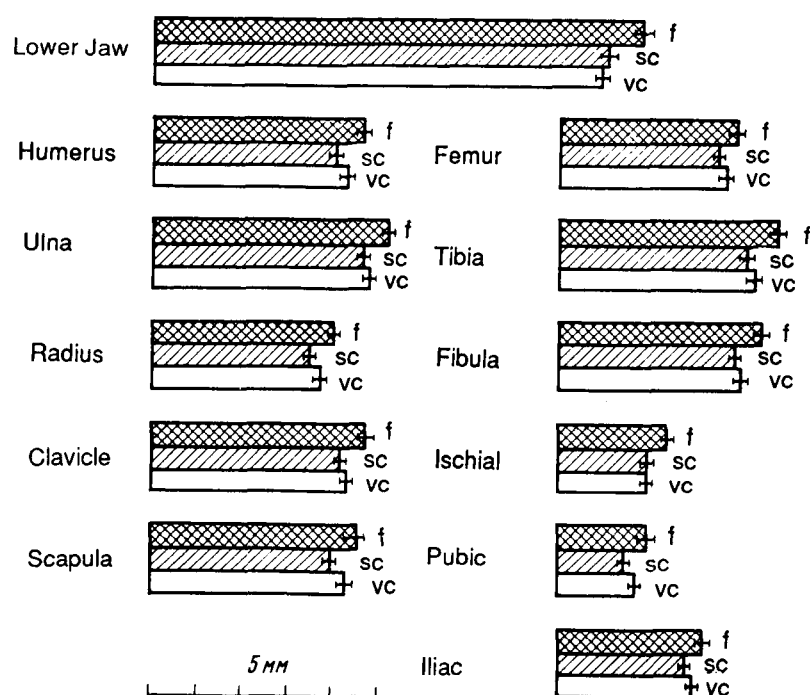


Figure 21: Dimensions of ossification sites in the skeletons of neonate rats

P976(21/89) Serova LV (U.S.S.R.), Alberts J (U.S.A.), Anasenko ZI (U.S.S.R.), Keefe D (U.S.A.).

Growth and development of neonate rats in their first month of life.

In: M143(21/89) Gazenko O.G. (editor) *Ontogenez mlekopitayushchikh v nevesomosti [Ontogeny of Mammals in Weightlessness]*

Moscow: Nauka; 1988; pages 82-88.

Developmental Biology, Early Postnatal Growth and Development; Neurophysiology, Musculoskeletal System; Perception, Sensory Physiology

Rats

Space Flight, COSMOS-1514

Abstract: This chapter describes the first month of life of neonate rats whose mothers flew on COSMOS-1514 during days 13-18 of pregnancy. During the postnatal period, eight neonate rats were left with each mother in the flight, synchronous, and vivarium groups for further physiological research. However, death rate in the first week of life was higher in the experimental group (19%) than in the synchronous (2.5%) and vivarium (0%) controls ($p < 0.001$; $p < 0.05$). Postnatal deaths occurred in only two of the four flight litters. In the litter of one of these mothers, three neonate rats died during their first day of life; during the period between days 4 and 7 after birth, three more rats from the flight group died.— one belonging to this same litter, and two offspring of another mother. The dead rats received milk but either had not gained weight or had gained weight significantly more slowly than the other animals. When the rats were autopsied, no structural anomalies were observed. Thus cause of death was likely to be changes in metabolism leading to decreased general resistance in the neonates. It is well known that one of the reasons for perinatal death is hypoxia occurring during pregnancy or in birth complications. Analyzing the duration and course of the births in individual animals, one might conclude that the difficult, prolonged births by the two mothers. led to more severe hypoxia than occurs during normal birth, and was the reason for the higher incidence of perinatal deaths of the animals.

As a result of these deaths, research subjects for the physiological research during the postnatal period numbered 26 rats in the flight group, 40 rats in the vivarium control group and 39 in the synchronous group.

During the first weeks of these rats' lives, the major focus of observations was on rate of growth and development, motor activity, particularly ability to coordinate movements during various provocative tests, and development of the sensory systems: tactile and vestibular sensitivity, hearing, vision, and smell.

On day 1 after birth, the rats of each litter were tagged; each rat was weighed daily for 20 days between 9:00 and 10:00 a.m. on scales accurate up to 0.01 g. The results of the weighing are presented in Figure 27. At all observation times, the mean body weight of the animals in the experimental group was 1-5 g below that in the vivarium control, but higher than that in the synchronous group. This is consistent with the idea that the weight gain lag noted in the flight group is due to flight factors other than weightlessness.

At the same time, a detailed analysis of the individual data revealed a greater variability in the weight of flight rats than within the control groups. At some observation intervals variability in the weight of the flight group was twice that of the control groups.

Three tests were used to evaluate vestibular function in the neonate rats: ability to turn over from a supine position (on days 2, 3, 4, 7, and 8 of life); capacity to turn against gravity on an inclined (-20°) plane (on days 1, 5, 6, 9, and 150) and a test on a rotating platform (on days 2, 3, 5, 7, and 9 of life).

Turning over from a supine position is a standard way to assess the vestibular function and motor activity of neonates. The neonate rats were placed on their backs on a level surface, and held down by light pressure of the experimenter's finger. When and whether they were able to turn over into a normal position after the finger was withdrawn was recorded. During the test, the behavior of the rats was recorded using a video camera located directly above them. The platform on which the rats were tested was surrounded by mirrors placed at an angle (Figure 28), making it possible to photograph and analyze the movements of the animals from various perspectives. During the test on day 2 of their lives, only 6% of the rats in the vivarium control (2 out of 32) were able to perform the movement in less than 30 seconds, while the corresponding figure for the flight group was 24% and for the synchronous control group it was 22%. During subsequent testing, the differences between the groups diminished and on days 4 and 7 there was no difference in time taken by the rats of the experimental and control groups to turn over from their backs. The pattern of use of the individual muscle groups in performing this movement was identical in the experimental and control groups and was normal and typical for the age of the rat.

The next test evaluated the capacity of the neonates to reorient themselves against the force of gravity, manifesting the so-called "negative geotaxis" reaction. This test is indicative of vestibular function, since it requires appropriate perception of the head-down position; as well as strength and motor coordination. The neonate rats were placed on an inclined platform (-20°) with their heads lower than their bodies (Figure 29). Their behavior was recorded with a video camera above them, as for the preceding test. The number of neonate rats manifesting "negative geotaxis" in 30 seconds was recorded; the task was considered accomplished if the neonate rats performed active movements and turned their bodies no less than 45° from the starting head-down position. During testing on the day after birth, 31% of the rats in the flight group and 63% of the rats in the vivarium control group passed the test. Only a portion of the rats in the vivarium group (16 animals in all) were tested, making conclusions difficult. On day 5 of life, the differences between the flight rats and the control group on this test diminished. Performance of a full turn on an inclined plane (in head-down position) is a relatively difficult task for neonate rats and requires significant muscular strength. On day 6 of life, the number of rats capable of performing a full turn was 48% in the experimental group; on day 9 this figure reached 88% and was reliably greater than the control level ($p < 0.01$). On day 15 no differences were found between groups.

The next test involved a rotating platform: the neonate rats were placed in the center of a round arena 9 cm in diameter, rotation lasted 30 seconds with a rate of 33 revs./minute; the rats were observed during rotation and after its termination using a video camera located above the rotating platform. In response to this test, neonate rats typically demonstrate an unconditioned compensatory reflex: the head turning in the opposite direction from direction of rotation (Figure 30). Tests were performed from day 1 to day 7 of life, when the rats' eyes were still shut; thus their reaction to rotation was determined only by the animals' perception of angular acceleration during rotation. The experimental group contained a greater number of rats manifesting this unconditioned reflex on days 1, 2, and 5; intergroup differences were especially significant on day 5 ($p < 0.05$). Subsequently, observation of this reaction was complicated by the masking of the reflexive response by voluntary movements.

The authors conclude that the vestibular system of neonate rats exposed to space during a portion of the prenatal period functions normally after birth, and in some tests (rotating platform) is even more sensitive than in control animals. The motor activity of the neonate rats and their capacity for motor coordination in performing the set of tests described above in the flight group was no worse —and sometimes better — than that of control animals.

On days 12, 15, and 18 of the rats' lives, experimenters assessed the physical work capacity of the neonate rats as indexed by the time they were able to hold onto a cross-bar. The results are presented in Figure 31. At all points, flight group rats were able to support themselves for a somewhat shorter time than the animals of the synchronous and vivarium control groups ($p < 0.05$). However, the intergroup differences were very small.

Tactile sensitivity was measured during the first days of the rats' lives on the basis of the motor response to being touched with a Frey irritation hair at various points on the torso. No differences were found between animals developing in weightlessness and control animals at any time.

The olfactory function was evaluated between days 3 and 15 of life on the basis of response to strictly graded smells. The stimulus used was amylacetate. It has been established that the development of sensitivity of rats to this smell is close to that of sensitivity to natural, biological olfactory stimuli. When the test was administered, the animals were placed in a special chamber, where the air had been filtered. Reaction to the stimulus was evaluated on the basis of changes in frequency and depth of respiration registered using miniature, loop-shaped sensors of elastic resin filled with mercury placed on the chests of the animals. Animals preadapted to the experimental chamber were given a baseline impedance plethysmogram for 30 seconds, then the olfactory stimulus was presented for 10 seconds; subsequently the odor source was removed and respiration was recorded for an additional 20 seconds. No reliable intergroup differences were observed either in the baseline (before presentation of the stimulus) respiration rate, which increased identically with age in all three groups, nor in the nature of reactions to the olfactory stimulus.

A special chamber, (Figure 32), was used to evaluate the animals' hearing. Testing was performed on day 14 of life immediately after the rats opened their eyes, and then on days 19 and 20 of their lives. Tones with frequency of 4 and 40 kHz were used, since normal development of hearing progresses from perception of low to high frequencies. Reactions to sound were estimated on the basis of the animals' motor activity. On day 14 of their lives, 100% of the neonate rats in the experimental group reacted to the low noise, while none reacted to the high one. At this same point of development, 67% of the control rats reacted to the low tone and 17% to the high one. On days 19 and 20, 72% of the rats in the control group and 38% in the flight group ($p < 0.05$) responded to the high tone, while intergroup differences in response to the low tone were not significant. Thus, rats spending some portion of the prenatal period under conditions of weightlessness displayed some retardation in the development of hearing compared to animals in the control group.

The eyes of animals in the experimental group opened earlier than those of the control animals: on day 14 of their lives the eyes of 64% of the flight animals and only 37% of the controls ($p < 0.001$) were open. To evaluate visual function on the day after their eyes opened, the rats were placed in a special device (Figure 33) consisting of a transparent cylinder in the center of a large drum, the interior wall of which was covered with alternating black and white vertical stripes projected on the animals' retina at an angle of 1.5° . Preliminary experiments had shown that the angular resolution of the eyes of neonate rats, estimated on the basis of optokinetic reaction to slow rotation of the drum, is, under normal conditions, sufficient for perception of objects at this angle.

The test included a 20-second period of adaptation to the device, a 20-second period during which the drum rotated and the rats' reactions were recorded with a video camera (located above the animals being tested) and 20 seconds of drum rotation in the opposite direction. The results of the visual test showed good reactivity in the flight group animals. In this group, 93% of the animals were able to perceive a moving image at a visual angle of 1.5° , while in the vivarium

control the corresponding number was 87%. Intergroup differences were not statistically reliable.

To summarize the results of the observation during early postnatal ontogeny, it was found that flight animals had a higher incidence of perinatal death. However, the differences between the groups did not increase as growth and development and the functional demands made on the organs developing during space flight increased.

Although their flight on COSMOS-1514 lasted only 5 days, the experimental animals were exposed to weightlessness for approximately 20% of pregnancy, during a period which includes a number of critical points in physiological development. Thus it was natural to expect rather severe changes, especially in the vestibular system. However, this hypothesis was not confirmed. The flight neonates grew and developed normally, in a number of parameters only slightly behind the control and in other parameters even somewhat ahead of controls. The differences between the experimental and control groups, where they were observed, were slight and subsequently rapidly diminished, without having serious effects on the general pattern of development.

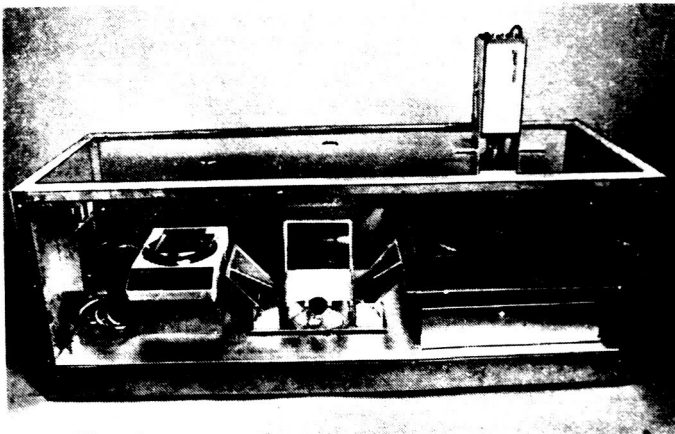


Figure 26

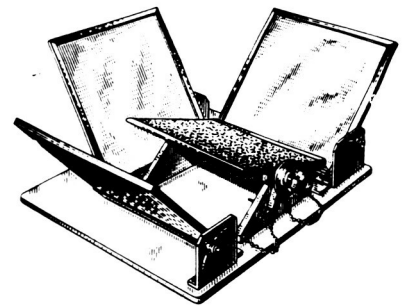


Figure 28

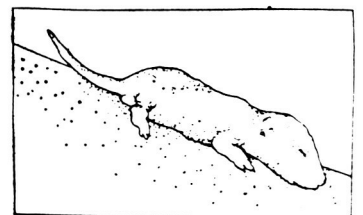


Figure 29

Figure 26: Incubator for work with neonate rats

Figure 28: Platform for observing motor activity of rats

Figure 29: Position of neonate rat in inclined plane test

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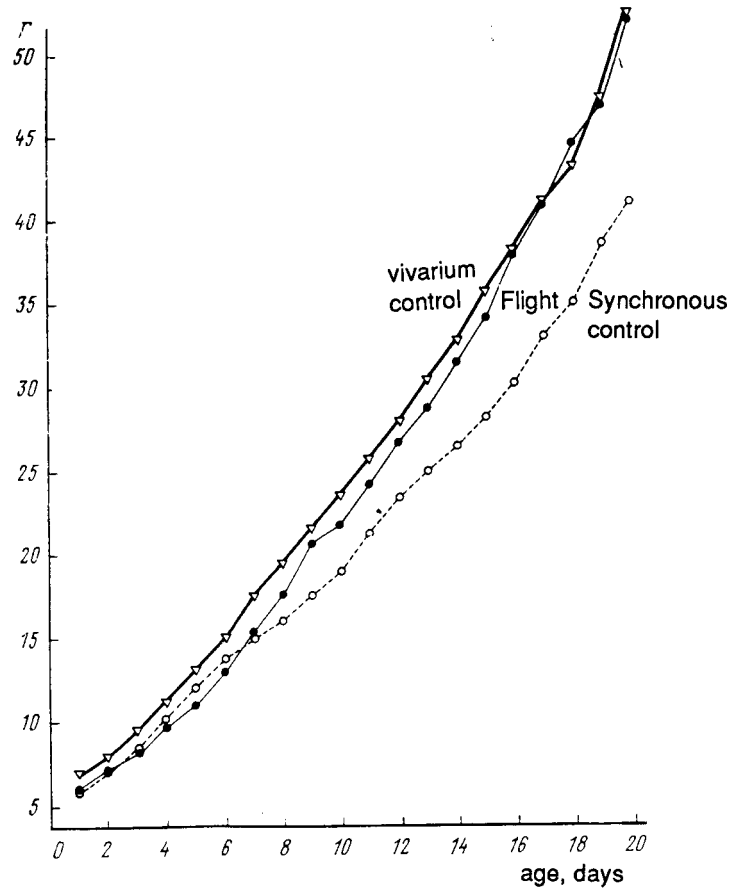


Figure 27: Increase in body weight over time

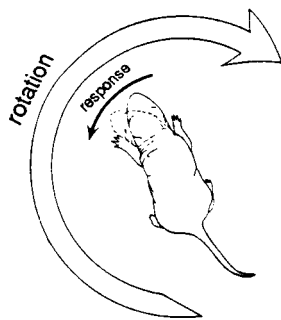


Figure 30

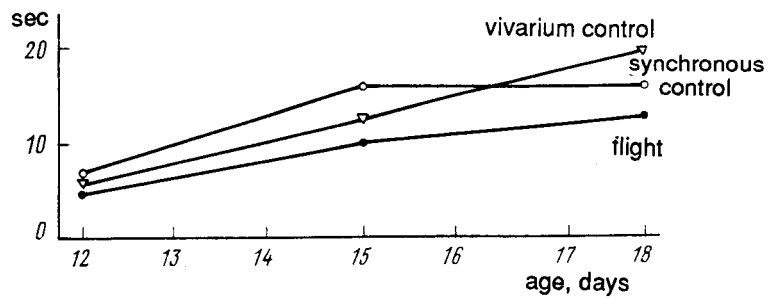


Figure 31

Figure 30: Position of the neonate rat in the rotating platform test
Figure 31: Time rats were able to hold on to a cross bar

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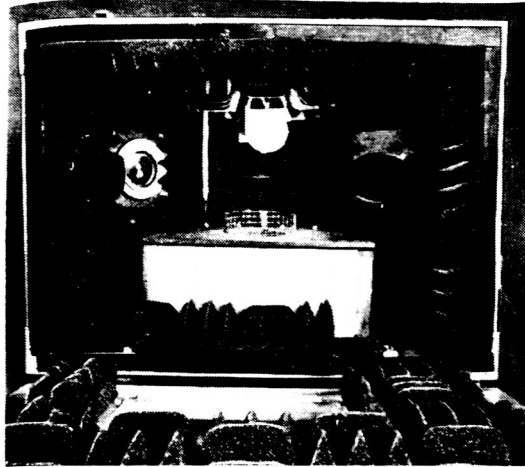


Figure 32

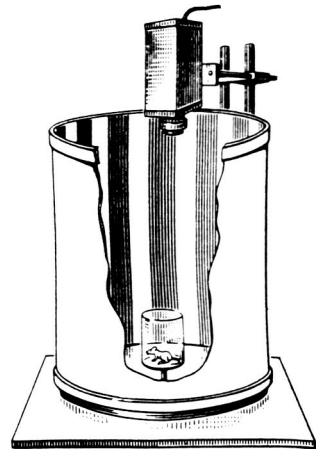


Figure 33

Figure 32: Chamber for studying the hearing of neonate rats
Figure 33: Apparatus for studying the vision of neonate rats

MONOGRAPH:

M143(21/89) Gazenko O.G. (editor).

Ontogenez mlekopitayushchikh v nevesomosti

Ontogeny of Mammals in Weightlessness

Moscow: Nauka; 1988.

[180 pages; 50 Figures; 46 tables; 410 references; 190 English]

Key Words: Developmental Biology, Reproductive System, Space Flight, COSMOS-1514, Equipment and Instrumentation, Hypergravity, Pregnancy, Endocrinology, Sympathetic-Adrenal System, Thyroid, Hematology, Hemopoiesis, Body Fluids, Metabolism, Lipids, Nucleic Acids, Enzymology, Cardiovascular and Respiratory System, Myocardium, Musculoskeletal System, Collagen, Bone Tissue, Cartilage, Skeletal Muscles, Pregnant Females, Ovaries, Psychology, Behavior, Neonates, Neurophysiology, Brain, Stress Response, Cytology, Germ Cells, Reproductive Function

Annotation: This monograph was produced by a group of authors from the U.S.S.R., Bulgaria, Hungary, East Germany, Poland, Czechoslovakia, United States, and France. It presents the results of the first embryological experiment on mammals conducted under space flight conditions on the COSMOS-1514 biosatellite, and of the preceding ground-based simulation studies. The data obtained concerning the role played by gravity in the processes of animal growth and development are summarized and interpreted. Future prospects for research in this area are discussed. This book is intended for specialists in space biology and physiology and other biologists with a broad range of specialties.

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EXOBIOLOGY

PAPERS:

P970(21/89) Telegina TA, Bekhoyev ID, Pavlovskaya TYe.

Composition and functional properties of abiogenically synthesized melanoidin pigments.

Izvestiya Akademii Nauk SSSR: Seriya Biologicheskaya.

1988(5): 788-792.

(15 references; 6 in English)

Authors' Affiliation: A. N. Bakh Institute of Biochemistry, U.S.S.R. Academy of Sciences, Moscow

Exobiology, Prebiological Evolution

Melanoidins, Abiogenic Synthesis

Catalytic Properties

Abstract: Organic catalysts of the melanoidin type are considered to be a significant link in the development of biocatalysis and thus in the genesis of life. The authors generated melanoidins and melanins in a water system of acetaldehyde (2.5%) and ammonium nitrate (1.5%) under exposure to ultraviolet radiation ($\lambda = 254$ nm). The resulting dark pigments were classified as melanoidins on the basis of their absorption spectra in ultraviolet, visual, and infrared areas of the spectrum and their solubility. The quantity of resulting pigments increased with increasing irradiation duration and increasing acetaldehyde concentration. It is argued that constant ultraviolet radiation in the absence of an ozone shield could have led, during the prebiological era, to the accumulation of significant quantities of melanoidin pigments from various amino and carbonyl compounds. Presence of quinoid groups in the experimentally generated pigments was demonstrated by the luminescence method and infrared spectroscopy (absorption in the 1660 cm^{-1} band). Presence of phenol groups was demonstrated by infrared spectroscopy (absorption in the 1160 and 1400 and 3400 cm^{-1} bands) and chemical analysis.

It was proposed that the quinoids found in the melanoidins could allow the latter to function as catalysts for redox processes since quinons are hydrogen and electron carriers in photosynthesis and biological oxidation. To test this proposal the catalytic activity of the melanoidins was compared to that of oxidoreductases. A solution of hydrogen peroxide was poured into a solution of methylene blue and ascorbic acid through a monolayer film of peroxidase or a thin film of melanoidins. The resulting oxidized form of methylene blue was subjected to colorimetry. The speed of the reaction in the presence of the enzyme or melanoidin was compared to the case where neither substance was present. Melanoidins accelerated the reaction by a factor of two. It is not stated whether this acceleration was greater or less than that of peroxidase.

Two systems of substrates: ethanol - NAD and ethanol-tetrazol were used to study the dehydrogenase-like effects of the melanoidins. It was found that, aside from acting as a catalyst, the melanoidin could also act as an electron donor with these systems, and this was taken into account when results were analyzed. For the tetrazol system, 0.4 ml 3(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazol bromide in a 1% solution of triton X-100 was added to 2 ml melanoidins in a test tube. The resulting solution was boiled and left in the dark for 20 minutes. The optical density of solutions of reduced forms of tetrazole (1, 0.5, 0.25, 0.12 and 0.06 mg) obtained was measured at a wavelength of 600 nm and compared to a control containing the corresponding amounts of tetrazole with ascorbic acid as a reducer. The

absorption of the melanoidins at this wavelength was subtracted. The data obtained indicated that the reducing capacity of these melanoidins was comparable to that of ascorbic acid. The second group of tests used a system of 2.5 ml 0.1 M glycine buffer, 0.1 ml 96% ethanol and 0.12 ml $1.5 \cdot 10^{-2}$ M solution NAD and a 0.5 ml solution of methanoidin ($2 \cdot 10^{-3}$ M). Absorption at 340 nm was measured for the reduced NAD forming as a result of reactions with ethanol. Reactions were compared to a control condition utilizing NAD and melanoidin to account for the direct reduction of NAD by melanoidin and another control containing ethanol and melanoidin. Computations showed that the catalytic activity of melanoidins is one ten-thousandth that of alcohol dehydrogenase, when the latter is used as a catalyst with this substrate system.

A substrate system of ethanol-tetrazol was used to determine the dehydrogenase activity of the melanoidins. A total of 0.15 ml 3(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazol bromide in a 1% solution of triton X-100, 0.1 ml 96% ethanol and 0.2 ml catalyst (standard melanoidins or the abiogenically formed melanoidins, or a solution of alcoholdehydrogenase) was added to 2.5 ml 0.06 phosphate buffer. Air was pumped out and the samples were maintained in the dark for 1.5 hours. Optical density of the reduced forms of tetrazole was measured at wavelength of 600 nm and compared to a control consisting of tetrazole and the corresponding catalyst. It was found that the abiogenically synthesized melanoidins had a significant catalytic effect, although this was considerably less than that of alcohol dehydrogenases.

The authors conclude that the catalytic properties of the abiogenically synthesized melanoidins are important in prebiological evolution, since availability of appropriate catalysts was essential for the complexity of carbonaceous compounds to increase and thus the prerequisites required for life to occur

Table: Reduction of tetrazol in the presence of a catalyst

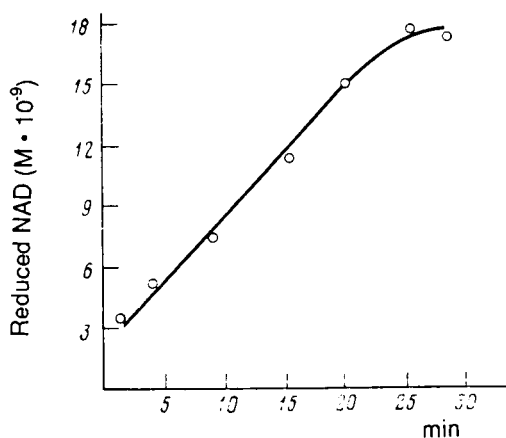


Figure 1

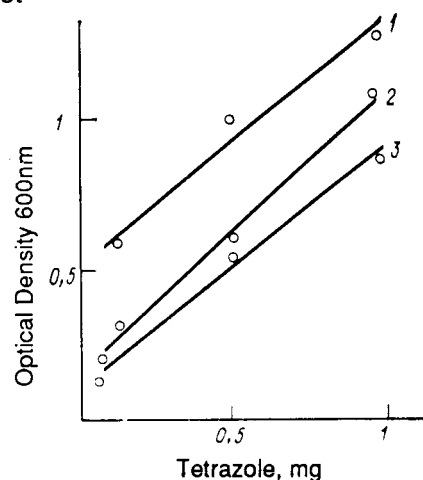


Figure 2

Figure 1: Accumulation of melanoidin pigments as a function of duration of irradiation of a system of acetaldehydes (2.5%)- ammonium nitrate (1.5%). Ordinate: absorption of melanoidins at 420 nm; abscissa - time, hours. [sic., graph itself says minutes]

Figure 2: Reduction of 3(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazol bromide by ascorbic acid (1), standard melanoidins (2), and melanoidins obtained in a system of acetaldehydes — ammonia salts (3). Ordinate: absorption at 600 nm of reduced form of tetrazole; abscissa: quantity of tetrazole produced by the reaction, mg.

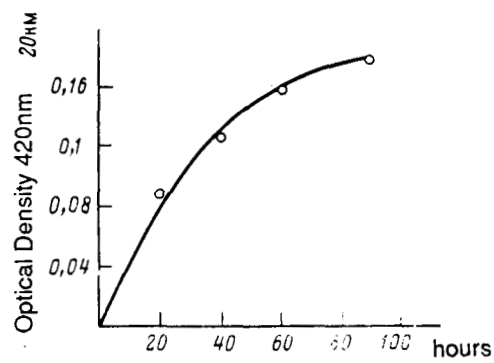


Figure 3

Figure 3: Kinetic curve of the progress of the reaction in an ethanol — NAD system in the presence of melanoidins obtained in the system of aldehyde — ammonium nitrate.

Ordinate: quantity of reduced NAD (M.10-9); abscissa — time, minutes. [sic., graph itself says hours]

P980(21/89) Ivanov IM.

Potential for searching for chemolithoautotrophic microorganisms on Mars.

Abstract of talk presented at the meetings of the Second U.S./U.S.S.R. Joint Working Group on Space Biology and Medicine. September 15-24, 1988, Washington D.C.

Author's Affiliation: Institute of Microbiology, U.S.S.R. Academy of Sciences.

Exobiology

Microbiology, Chemolithoautotrophic Bacteria

Mars, Life

Abstract: In his talk, Dr. Ivanov proposed that the search for lower forms of modern life in the soil of Mars focus on chemolithoautotrophic microorganisms. The proposed program is currently under discussion by Soviet biologists and geochemists and, if it is approved, may be implemented as early as the Soviet or Soviet-American Mars mission projected for 1994. Plans for this mission call for landing a self-propelled rover vehicle carrying 30-40 kg of scientific equipment. The rover is expected to be functional and active for no less than 1 year, covering a route across the surface of Mars of no less than 100 km. Although the exact nature of the equipment to be carried by the rover has not yet been determined, one likely type of apparatus is a drilling rig that will be capable of obtaining samples not only from the surface of Mars but from a depth of 10-15 m. The landing site for the descent vehicle and the region in which the rover will operate will be determined on the basis of preliminary satellite data on Mars. Long-term plans call for returning samples of Martian soil to Earth for intensive study.

Heterotrophic and photoautotrophic microorganisms in the surface layers of the Martian regolith were the two major targets of searches for living organisms in the Viking Program. The results of gas exchange and radioactive $^{14}\text{CO}_2$ inclusion experiments on Martian soil and follow-up model experiments support the hypothesis that the surface layers of the Martian regolith contain peroxide compounds which, when the soil is moistened, emit oxygen, as observed during the gas exchange experiments. A number of other hypotheses were also formulated to substantiate the possibility of abiogenic synthesis of organic substances on Mars.

Since the possible presence of chemical agents in the upper layer of the regolith would make interpretation of data ambiguous, it has been recommended that future searches for life on Mars obtain samples from the subsurface layers of Martian soil. However, this approach precludes the possibility of searching for photoautotrophic bacteria and focuses on searching for heterotrophic microorganisms. Such microorganisms require preexisting organic substances. Dr. Ivanov agrees with the strategy of searching for Martian microorganisms in the rock mass of the regolith, where microorganisms would be better protected from cosmic radiation and other severe environmental conditions on the surface of Mars, but suggests that no data from the Viking missions provides evidence of any detectable quantity of organic substance in the Martian regolith. A current proposal to concentrate on searching for heterotrophic life in the soil profile cuts of layered sedimentary rock located in "river" valleys and canals of Mars is based on the supposition that these sedimentary rocks were formed in a hypothetical epoch of more or less active development of Martian paleolife. However, the majority of researchers agree that the very fact of the existence of paleolife on Mars may be reliably established only after a detailed geochemical study of the Martian rocks in laboratories on Earth, that is, during the second stage of the planned research on Mars, which depends on returning samples to Earth.

In view of the rather well established absence of detectable quantities of organic substance in the samples analyzed by the Viking instruments, and the absence of reliable proofs of the presence of organic substance in other Martian rocks, Dr. Ivanov discusses the desirability of concentrating the search on microorganisms that do not require the presence of preexisting

organic compounds for their metabolism — the so-called chemolithoautotrophic microorganisms.

The sole source of carbon that these microorganisms require for cell synthesis is carbon dioxide. The energy sources for these microorganisms are redox reactions, while the oxidized substrate consists of inorganic reduced compounds of sulfur, carbon and nitrogen, such as H_2S , metallic sulfides, elemental sulfur, thiosulfates, carbon monoxide, methane, ammonia, and nitrites.

Chemolithoautotrophic bacteria oxidizing hydrogen and reducing compounds of iron, methane, and manganese have also been rather thoroughly studied. The majority of chemolithoautotrophic microorganisms are aerobic microorganisms, in which the final acceptor of electrons is oxygen. However, a number of specialized groups of these bacteria, such as sulfate-reducing, methane-forming, denitrifying, sulfur-reducing and acetate-forming, may also develop in anaerobic conditions, using bound oxygen of sulfates, nitrates, and carbonates, and also element sulfur, for anaerobic "oxidation" of hydrogen.

The main geochemical result of the activity of chemolithoautotrophic bacteria is the synthesis of organic substance from inorganic compounds which, unlike photosynthesis, may occur in the absence of sunlight.

At the present time, there is enough empirical data to support the assertion that chemolithoautotrophic microorganisms play a leading role in biogeochemical processes in at least two stages of the carbon, sulfur, metal and nitrogen cycles. First, they actively participate in oxidation of reduced compounds of these elements on the boundary between aerobic and anaerobic systems in bodies of water, and in underground water and soils. Reduced gaseous and dissolved compounds in these ecosystems are associated with the processes of anaerobic decomposition of organic substances.

The second stage in the element cycle is associated with the oxidation by chemolithoautotrophic microorganisms of reduced products emitted in volcanic and hydrothermic processes. As soon as these products are exposed to low-temperature conditions ($100^\circ C$ and below), they become the prey of first anaerobic and then aerobic chemolithoautotrophic bacteria.

Pure cultures of many types of microorganisms, including archaebacteria, were obtained from the hot springs of Yellowstone by T. Blok and colleagues and from Soviet hot spring sites by Zavarzin, Gorlenko and others. Soviet, American, and Japanese microbiologists and geochemists have accumulated a great deal of empirical data concerning the geochemical activity of various groups of chemolithoautotrophic bacteria in crater lakes, thermal springs, and sulfur-sulfide sites of volcanic genesis.

These works demonstrate that various groups of chemolithoautotrophic bacteria show high biochemical activity under conditions of extreme temperature and high acidity characteristic of sites of volcanic and hydrothermic activity on Earth. The role of microorganisms participating in the sulfur cycle has been demonstrated. As noted above, the most important physiological characteristics of chemolithoautotrophic bacteria are their lack of dependence on organic substances, and their ability to produce all the organic compounds of a living cell from carbon dioxide. Study of ecosystems of crater lakes and hot springs of volcanic regions has shown that it is precisely these microorganisms that are the major producers of organic substances in such systems. Thus, chemolithoautotrophic microorganisms oxidizing reduced gases of volcanic genesis become the first link in the trophological chain transmitting the energy of volcanic emanations to invertebrate animals inhabiting the crater lakes and springs. Such ecosystems are unique on Earth in their freedom from dependence on sunlight.

EXO BIOLOGY

Microbiological investigations of ecosystems in the area of deep-water, high-temperature springs of the rift zones, by Dr. Holger Yannish, and others have demonstrated the prevalence of chemolithoautotrophic bacteria and their importance as a main source of organic nutritive substance for other members of the ecosystem.

Dr. Ivanov argues that in view of these data it is a completely logical possibility that these organisms, which are independent both of the solar energy and the presence of organic substance, exist in Martian rocks, primarily in those regions of Mars that are rich in volcanic formations. The so-called shield volcanic formations are one of the characteristic geomorphological features of the surface of Mars.

Geologists have concluded that Mars has the largest volcanoes discovered in the solar system. The largest of them, Olympus Mons, reaches a height of 25 km, with the diameter of the foundation of the volcanic cone on the order of 600 km and the diameter of the main caldera on the order of 65 km.

Currently we have no direct proof of modern volcanic or postvolcanic activity on Mars, which would result in the emission of reduced gases that could serve as energy sources for chemolithoautotrophic bacteria. However, there is no reliable data indicating the absence of a stream of reduced gases from the depths of the Martian lithosphere.

The very high concentration of sulfur and sulfate on the surface layer of the Martian regolith, discovered by the analytic equipment of both Vikings in two spatially distant landing sites, can be taken as indirect proof of powerful volcanic flows to the surface of Mars.

By the beginning of the Mars Rover mission, additional geophysical satellite data may have been obtained on surface temperatures and the magnitudes of the thermal stream in various regions of the planet. Such data could be used to target the landing site of the rover and its route over the surface of Mars to areas most likely to contain signs of chemolithoautotrophic bacteria.

The complete absence of modern volcanic processes and the emission of reduced gases do not prevent the development of chemolithoautotrophic bacteria in areas of ancient volcanic activity. Such bacteria have been identified in volcanic rocks of the Soviet Union where volcanic processes occurred 80 million years ago.

In selecting a site for sample selection in the search for live chemolithoautotrophic microorganisms, preference should be given to regions with high concentrations of volcanic formations. Regions that show signs of positive thermal anomalies should be considered first. Regions with signs of past volcanic activity may provide more favorable thermal conditions on the surface rocks, and thus greater likelihood of liquid soil moisture, as well as a chance of finding streams of reduced volcanic gases. Because of the composition of trace gases in the Martian atmosphere and the chemistry of the surface samples of regolith, priority should be given to the search for aerobic chemolithoautotrophic bacteria of the sulfur cycle and methane-oxidizing bacteria. However, given the low concentration of oxygen in the Martian atmosphere, the possible existence of anaerobic chemolithoautotrophs, such as sulfate-reducing, methane-forming and acetate-producing bacteria, should also be considered. Dr. Ivanov proposes that American-designed research apparatus used in the Viking mission can be adapted to search for chemolithoautotrophic microorganisms. He also suggests that intensified study of the physical, biological, and chemical characteristics of these organisms and their geochemical activity on Earth would be of major interest in itself.

GRAVITATIONAL BIOLOGY:See:Neurophysiology P949

HABITABILITY AND ENVIRONMENT EFFECTS

(See also: Operational Medicine P958)

PAPERS:

P959(21/89)* Surovtsev NA, Nazarov LYu, Lukicheva TA, Vasyukov GV.

The effects of carbon monoxide and ammonia on humans wearing protective suits (personal safety devices).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 72-76; 1988.

[22 references; 3 in English]

Neurophysiology, Cardiovascular and Respiratory Systems, Human Performance
Humans

Habitability and Environment Effects, Protective Suits, Ammonia, Carbon Monoxide

Abstract: Ammonia and carbon monoxide are among the most potentially harmful products to which humans may be exposed in airtight environments, including pressurized protective suits. This work investigated the effects of these chemicals on humans when simulating some of the conditions found in pressurized protective suits (lowered air pressure, breathing of pure oxygen). Subjects were housed in a barochamber at rest with depressed barometric pressure (308 mm Hg) under comfortable microclimate conditions. They breathed either pure oxygen, (condition I, control) or oxygen with the addition of carbon monoxide (II and III, carbon monoxide concentration 60 and 120 mg/m³, respectively), or oxygen with the addition of ammonia (series IV and V, ammonia concentration 20 and 40 mg/m³, respectively). The authors had previously recommended 60 mg/m³ carbon monoxide as acceptable for 2-hours of exposure in an pressurized protective suit. The maximum acceptable dose of ammonia is 20 mg/m³ for a working area. The maximum acceptable concentration of ammonia for a breathing medium, however, is only 5 mg/m³. A total of 7 males participated in 88 exposure sessions lasting 12 hours each. The following parameters were measured as indicative of central nervous system functions: sway of body in upright posture (measured on a stabilimeter); normal physiological tremor of the fingers; critical flicker fusion frequency; variation in visual motor reaction time; static endurance; and a number of clerical (proofreading) tests. Status of the cardiovascular system was estimated from heart rate, blood pressure, EKG parameters, respiration rate, and respiratory minute volume. Concentration of ammonia was measured in urine and concentrations of carboxyhemoglobin, urea, and residual nitrogen, were measured in blood. Activity of whole blood catalases and cholinesterases were measured in serum. Hematological studies were performed before and after the experiment.

Respiration rate remained virtually unchanged in conditions I, II, and III. No effects were detected in conditions I and II in heart rate, blood pressure, or the central nervous system or performance tests. The most extreme changes were noted in condition III (120 mg/m³ carbon monoxide). Nervous system parameters were adversely affected, reaching a minimum after 6 hours of exposure. Performance parameters also decreased. By the end of the 12-hour period heart rate had decreased from a mean of 79 to a mean of 70. Breathing pure oxygen led to decreased carboxyhemoglobin in blood. Addition of carbon monoxide increased this parameter in blood, to a greater degree for the higher dosage. Catalase activity in whole blood did not change in any of these three conditions; however, activity of choline esterases in serum increased in condition III. Subjects reported feeling well in conditions I and II, but complained of weakness and headache in condition III. Increased carboxyhemoglobin in blood was closely associated with decrements in psychomotor performance.

HABITABILITY AND ENVIRONMENT PARAMETERS

Subjects in conditions IV and V reported feeling satisfactory. There were some noticeable effects on parameters in condition V: subjects in this condition complained of the smell, and of irritation of the eyes and throat. Respiration rate increased significantly, sway increased as did tremor, while static endurance decreased. Psychomotor performance was significantly altered in the majority of subjects. Urea and residual nitrogen increased in blood. In condition IV (lower ammonia concentration), some decrement in nervous system parameters was noted, but was less severe than for the higher dose. The only change in chemical parameters was a non-significant increase in urea in blood. Other data in the literature cite a dose of 70 mg/m³ as irritating while here 40 mg/m³ was found to cause distress. Subjects in the current experiment found a concentration of 20 mg/m³ produced a barely detectable odor, although existing data indicate that 0.5 mg/m³ is the olfactory threshold for ammonia. The authors attribute the differences to the conditions simulating those of protective suits and stress the importance of considering the possible effects of such environmental conditions on tolerance for potentially toxic substances when developing standards.

HABITABILITY AND ENVIRONMENT PARAMETERS

P960(21/89)* Savina VP, Mukhamediyeva LN, Kalandarov S, Nikitin Yel.

Human response to chemical substances in a sealed living space.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 76-80; 1988.

[15 references; 3 in English]

Adaptation, Chemical Toxins, Ammonia

Humans

Habitability and Environment Effects, Sealed Environment

Abstract : The goals of this work were to study the formation of adaptive responses to long-term uninterrupted exposure to toxic chemical substances and to investigate the functional stress resulting from repeated exposure to relatively high concentrations of toxic substances of anthropogenic origin. The substance selected for study was ammonia, which continually pollutes sealed living environments. An environment 24 m^3 was selected; there were 8 subjects, aged 24-35. Two experimental conditions were run. The first condition lasted 42 days, during 37 of which concentration of ammonia in the atmosphere was $2.0 \pm 0.1 \text{ mg/m}^3$. In the second condition the same concentration of ammonia was present in the atmosphere during 30 of the 35 days subjects spent in the environment. On days 16 and 32 of the second condition, ammonia concentration was increased to $9.8 \pm 0.2 \text{ mg/m}^3$ over a 24-hour period. In both conditions, temperature was maintained at $20-21^\circ\text{C}$, humidity at 50-60%, oxygen at 20-21%, and carbon dioxide at 0.3-0.5%. Subjects ate a balanced diet of 3000 calories per day. Ammonia in exhaled air was measured by reactions with Nessler reagents. Blood parameters were measured on days 12, 18, 30 and 42 in the first conditions, and days 11, 16, 30, and 32 in condition 2. Urine parameters were measured on days 7-12, 13-18, 25-30, and 37-42 in the first condition and days 7-12, 16, 25-30, and 32 in the second. Blood ammonia was assessed using a method developed by Keller et al. Blood urea was measured by the diacetylmonoximine method and residual nitrogen using a Czechoslovak bio-test. Urea in urine was measured by a method described by Levine. The functional status of the sympathetic adrenal system was evaluated by excretion of catecholamines, measured fluorometrically. Activity of choline esterases in blood was estimated on the basis of the activity of erythrocyte acetylcholinesterases and nonspecific cholinesterases of plasma, measured spectrophotometrically. Blood histamines were measured fluorometrically and serotonin using a method developed by Shuder.

The initial period of exposure to 2.0 mg/m^3 ammonia was marked by development of a nonspecific adaptive reaction, as shown by increased (by 25%) activity of acetylcholinesterases of erythrocytes, increased excretion of noradrenalin and DOPA, decreased blood histamine and serotonin. During this initial period, exhalation of ammonia was greatly increased, while concentration of ammonia and residual nitrogen in blood remained at baseline level. This equilibrium was maintained up to day 35 in condition 1, at which time ammonium nitrate and residual nitrogen in blood increased, as did urea formation, while exhalation of ammonia remained unchanged. This activation of ammonia binding and renal excretion was accompanied by increased adrenalin, noradrenalin, and DOPA in daily urine. At the same time, activity of cholinesterase and blood serotonin increased, suggesting activation of reactions to maintain homeostasis.

In condition 2, 24 hours of exposure to the higher dose of ammonia led to increased urea and ammonium nitrate in blood and greatly increased exhalation of ammonia. During the subsequent periods with ammonia concentration at the lower level, ammonia and urea in blood decreased, but remained elevated compared to levels before increased exposure. The authors conclude that adaptive responses to low doses of ammonia limit adverse effects, but do not prevent them completely. On the second exposure to the higher dose, the neutralization reaction was more extreme. Along with exhalation of ammonia, synthesis and excretion of urea increased. At the

same time, the level of residual nitrogen in blood increased. No effects were noted on catecholamines. Three days after subjects left the sealed environment, exhaled ammonia and residual nitrogen in blood returned to baseline, while blood ammonia remained somewhat elevated. The authors conclude that repeated exposure to higher concentrations of ammonia in an airtight environment increases binding and exhalation of ammonia without mobilizing the sympathoadrenal system or straining homeostatic mechanisms.

Table 1: Changes in concentration of catecholamines in daily urine

Table 2: Changes in activity of acetyl- and nonspecific choline esterases, and levels of histamine and serotonin in blood

Table 3: Changes in products of nitrogen metabolism in blood and urine and concentration of ammonia in exhaled air

HEMATOLOGY

(See also: Developmental Biology P974, M143; Psychology P979)

PAPERS:

P951(21/89) Popova IA, Afonin BV, Vetrova YeG, Drozdova TYe, Zagorskaya YeA, Kabitskiy YeN, Larina IM, Markin AA.

Homeostatic responses of the blood of rats in an experiment on the COSMOS-1667 biosatellite.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 39-42; 1988.

[6 references; 2 in English]

Hematology, Homeostatic Response; Enzymology; Endocrinology

Rats

Space Flight, Short-Term, COSMOS-1667

Abstract: This experiment investigated changes in rat blood after short-term exposure to space. Subjects were Wistar rats. A flight group (N=7) was flown for 7 days on board the COSMOS-1667 biosatellite. Vivarium (N=14) and synchronous control (N=7) groups were used. The latter was housed in a mock-up of the biosatellite, under conditions simulating dynamic flight factors. Experimental animals were sacrificed 4-8 hours after reentry; control animals were sacrificed after an analogous period. Experimenters measured the concentration of protein, glucose, creatinine, and electrolytes in heparinized blood plasma. Enzyme activity was measured using a biochemical analyzer and hormone activity using radioimmune assay. Products of lipid peroxidation and total antioxidative activity were also measured.

After 7 days in space, rats displayed significantly elevated levels of corticosterone, total protein, glucose, creatinine and phosphorus. Elevations were also noted in activity of alanine aminotransferase, lactate dehydrogenase, and total antioxidative activity of blood;; while concentrations of 11-deoxycortisol, testosterone, total and free thyroxin, and acid phosphatases activity were diminished. Since the concentrations of protein and activity of acid phosphatases and lactate dehydrogenase were altered equally in the synchronous control group, these changes are not attributed to weightlessness.

Evaluation of the functions of the adrenal cortex showed increased concentration of corticosterone in blood, as occurs after long-term flight. Increase of corticosterone (up to a factor of 2) was less than that which occurs after placement in immobilization cages, and is attributed to a moderate degree of stress associated with flight. Other stress-related responses were hormonal changes, blood glucose increase, and stimulation of the antioxidant system. Increases in blood concentration of inorganic phosphates were tentatively attributed to the beginning of destructive processes in the bones and muscles, as was creatinine increase. However, these changes may also simply result from hypohydration and altered kidney function.

HEMATOLOGY

Table: Composition of rat blood

Component	Group		
	Vivarium	Flight	Ground Control
Corticosterone, ug%	21.3±1.43	40.3±3.99*	19.5±4.20
11-Deoxycortisol, pg/ml	640.3±15.7	566.7±35.5*	604.3±31.0
Aldosterone, pg/ml	229.4±9.8	193.4±17.3	180.0±16.8*
Testosterone, ng/ml	6.56±0.84	1.60±0.18 **	5.05±0.52
Parathyroid hormone, ng/ml	0.97±0.08	0.93±0.01	0.96±0.04
Thyroxin total, ug%	6.53±0.14	5.25±0.14***	7.59±0.57
Thyroxin, free ng%	2.01±0.04	1.52±0.05***	2.03±0.14
Trilodothyronine, ng%	38.1±5.1	40.5±6.8	52.1±6.9
Sodium, mmole/l	150.0±0.29	153.5±1.6	153.6±1.6
Potassium, mmole/l	6.08±0.09	6.50±0.20	5.59±0.11
Calcium, mmole/l	3.01±0.05	2.95±0.05	3.06±0.04
Inorganic phosphorus, mmole/l	2.41±0.09	3.55±0.29*	2.33±0.07
Glucose, mmole/l;	9.10±0.37	11.3±0.81*	9.3±0.09
Total Protein, g/l	68.7±0.8	72.6±1.4*	72.6±0.8*
Creatinine, mmole/l	74.3±1.8	96.0±4.8*	69.6±2.2
Aspartate aminotransferase, meqv/l	198.5±9.9	187.5±22.6	158.3±11.7
Alanine aminotransferase, meqv/l	46.3±3.6	63.8±5.8*	48.7±3.0
Alkaline phosphatase, meqv/l	189.0±9.8	188.0±13.0	241.0±18.0*
Acid phosphatase, meqv/l	24.9±1.27	16.1±2.97	14.0±1.89*
Creatine kinase, meqv/l	11,830±990	11,205±309	8480±979*
Glutamate dehydrogenase, meqv/l	5.6±0.6	7.7±0.9	5.7±0.2
Lactate dehydrogenase, meqv/l	447.0±27.4	322.0±26.6*	343.0±21.4*
Malonic dialdehyde, nmole/l	3.20±0.2	3.17±0.17	3.86±0.34
Total antioxidant activity, %	76.6±3.7	87.4±2.7*	76.6±4.0

* p< 0.05; ** p<0.01; *** p <0.001 compared to vivarium control parameter. Student's t was used.

HUMAN PERFORMANCE

(See also: Body Fluids P961; Habitability and Environment Effects P951)

PAPERS:

P946(21/89)* Yegorov VA, Frantz BS, Sokolov VA, Pomerantsev NA.

A method for using central electroanalgesia as a means to correct functional status of flight personnel during a period of high workload.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 18-20; 1988.

[10 references; none in English]

Human Performance, Job Performance; Psychology, Psychophysical Parameters

Humans, Flight Instructors

High Workload, Electroanalgesia

Abstract: The authors tested the effectiveness of central electroanalgesia in flight instructors who frequently have to cope with very high flight workloads. Central electroanalgesia was applied in a course of 4-5 daily sessions lasting 40-50 minutes each. Electrodes were mounted on gauze and attached to the forehead and below the mastoid process. Frequency of electrostimulation impulses were 1500 Hz with duration of 0.2 and mean current of 0.7-1.0 mA (depending on individual differences in sensitivity). Subjects were two groups of flight instructors, aged 23-27. The 18 members of the first group were exposed to central electroanalgesia, while 25 subjects served in a control group. Subjects underwent psychophysiological examination at the beginning and end of a period of high workload. The functional status of each pilot was assessed in the morning, the evening before the day he was going to fly, and after a flight period. Functional status was assessed using such psychophysiological criteria as, determination of critical flicker fusion frequency (CFFF), galvanic skin response (GSR), and estimate of 10 second intervals (TIE). Professional work capacity was assessed during the experimental flight and on training simulators. Experimental flights, which lasted a total of 15 minutes, were divided into stages lasting 3 minutes each in which maintenance of the flight course, physiological parameters (pulse rate (PR), respiration rate (RR) and respiratory minute volume (RMV), and information processing parameters were assessed. A stress index was computed as follows:

$$SI = \frac{8RMV_f + 4RR_f + PR_f + CA_f}{8RMV_b + 4RR_b + PR_b + CA_b}$$

in which CA is the number of correct answers in an information processing task. A coefficient of effectiveness was also computed according to the following formula:

$$CE = \frac{PC_f + PC_a}{SI}$$

In which PC_f is processing capacity of the pilot while piloting the trainer (in bytes/second) and PC_a is processing capacity for an auxiliary task. PC_f was measured on the basis of accuracy of maintaining set course parameters. A summary index of pilot error was also computed from flight parameters. In the control group, pilot performance parameters deteriorated toward the end of a period of high workload, even on days when pilots were not flying. Parameters suggested cumulative development of fatigue. Central electroanalgesia had a salutary effect on these parameters, with no signs of cumulative fatigue evident.

P947(21/89)* Bobkov YuG, Yepishkin AK.

The effect of actoprotectors on the work capacity of operators under conditions simulating certain space flight factors.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 20-23; 1988.

[7 references; none in English]

Human Performance, Work Capacity

Humans, Operators

Pharmacological Countermeasures; Actoprotectors, Bemityl; Antigravity Suit, Acceleration, Coriolis, Posthypnotic Suggestion, Sleep Deprivation

Abstract: "Actoprotector" is the Soviet name for a new class of stimulants based on products of gutimine (sic., misprint for glutamine?) and mercaptobenzimidazol. This class of drugs is said to increase physical and mental work capacity, general resistance to acute oxygen deprivation, humidity, high temperatures, and vestibular stimulation, and to have low toxicity. The current study investigated the effects of the actoprotector bemityl (chemical composition unknown) on operator performance of humans exposed to simulated space flight factors. Subjects in the experiment were 12 healthy male operators aged 18-20. Subjects were assigned to a bemityl or placebo condition in a double blind procedure. Bemityl was administered twice in a dose of 0.25 g for the 3 days preceding the experiment (at 1000 and 1800 daily) and three times in same dose during the experimental period itself (at 200, 1000, 1800). The experimental design called for 56 hours of uninterrupted operator performance at compensatory or pursuit tracking (of a light on a CRT); identification and processing of visual information (signal identification in noise); and simple motor response to a sensory stimulus against the background of such space flight factors as simulated weightlessness, relative hypodynamia, and sensory deprivation.

Weightlessness was modeled by a number of factors: blood pooling in the upper body induced by an antigravity suit; vestibular discomfort induced by exposure to cumulative Coriolis acceleration until the development of moderate symptoms of motion sickness every 3 hours; subjective feeling of decreased body weight induced by post-hypnotic suggestion. Functional state was evaluated every 2 hours by recording heart rate and every 12 hours by EEG. Biopotentials were analyzed for alpha, beta, delta, and theta rhythms. Experimental material was analyzed and statistically tested using Student's t.

Control (placebo) subjects began to manifest disruptions in work capacity during the first hour of the experiment. For example, time to detect visual signals increased by a factor of 4.5. Between hours 24-28 of treatment, performance deteriorated progressively. Workers taking bemityl displayed a higher level of work capacity throughout the experimental period. The quality of their compensatory tracking was 10% better ($p < 0.05$), and error in pursuit tracking was 1.8 times lower than for operators in the control group. Time to detect a signal was 2.4 times lower than controls, but decrease in signal detection error was less pronounced, possibly due to visual fatigue. Sensorimotor response time was shorter by 17 msec ($p > 0.05$) in the group receiving bemityl. In experimental subjects, starting with hour 36 of the treatment period, delta and theta rhythms increased moderately, while alpha rhythms were decreased and beta rhythms elevated considerably from baseline. Symptoms of fatigue did not develop until 36-40 hours into the experimental period in subjects taking bemityl, while they began to occur in control subjects after 18-24 hours. The authors conclude that the results suggest that bemityl has a positive effect on operator work capacity during exposure to certain simulated space flight factors.

Figure: Effects of bemityl on the performance and physiological parameters of operators.

P971(21/89) Sysoyev VN.

The effects of duration and intensity of workload on the differential sensitivity of sensory systems.

Fiziologiya Cheloveka.

14(5): 786-788; 1987.

(9 references; 1 in English)

Author's Affiliation: S. M. Kirov Academy of Military Medicine, Leningrad.

Perception, Differential Sensitivity, Visual, Auditory, Tactile, Kinesthetic
Humans, Operators
Human Performance, Workload

Abstract: This study investigated the effects of duration and intensity of workload during operator performance of a visual task on differential sensory thresholds. Subjects were 32 healthy males, aged 19 to 22, divided into two groups each of which performed a different visual task. The first task involved matching the length of line segments using a set of standards from 0.5 to 15 cm in length. Subjects worked at their own speed. Accuracy of reproduction was the performance criterion. Subjects were tested for differential sensitivity before task performance and after the first and second hour of performance. In the second group subjects were required to track a signal moving on a complex sinusoidal path on an oscilloscope. In one low workload subgroup, 15 second rest pauses alternated with 25 seconds of tracking. In another high workload subgroup, instead of a rest pause subjects had to equate two simultaneously presented hemispheres for brightness. Both groups of subjects were tested before task performance and after a 60-minute performance period. Differential visual thresholds were determined by having subjects equate two simultaneously presented hemispheres for brightness. Differential auditory thresholds were determined by having subjects equate two sequentially presented sounds for loudness. Kinesthetic thresholds were determined by asking subjects to reproduce a particular pressure with their fingers against a spring. Differential tactile thresholds were determined by asking subjects to indicate whether the distance between the two arms of a caliper pressed to the forearm was the same as or different from a previously presented difference. There were 304 sessions in all.

After the first hour of work, the first group of subjects displayed an increase in the differential thresholds of the visual and kinesthetic systems, the systems involved in their task performance. As a rule, auditory threshold decreased and no changes were found in differential tactile sensitivity. After the second hour, there was a tendency for the differential thresholds of the systems being used to decrease, auditory threshold was virtually unchanged. Five subjects showed the same effects after 2 hours of work as after 1 hour, while effects for the other 5 were in different directions. The first subgroup of group 2, showed an increase in differential visual threshold and a decrease in auditory and motor thresholds. In the second subgroup, visual and auditory thresholds tended to decrease while kinesthetic threshold tended to increase. Changes in tactile threshold were not significant. For the second subgroup of group 2, there were considerable fluctuations in differential visual threshold as task performance continued. No correlation was found between threshold and tracking performance over time.

The authors conclude that increasing duration of operator performance of a visual task leads to a decrease in differential visual and kinesthetic thresholds. When intensity of workload increases, a decrease in visual differential threshold is accompanied by an increase in kinesthetic threshold. Differential auditory sensitivity improved during task performance but was virtually independent of workload duration or intensity. Individual differences in the responses of subjects can be explained by differences in the point at which sensory systems pass from one functional state to another.

HUMAN PERFORMANCE

Table 1: Dynamics of differential thresholds of sensory systems as a function of duration and intensity of operator workload in performance of a visual task in subjects in group 1

Table 2: Changes in differential sensitivity in sensory systems of individuals in group 2

Figure: Relationship between dynamics of differential visual thresholds and dynamics of tracking errors

LIFE SUPPORT SYSTEMS

PAPERS:

P981(21/89) Meleshko GI.

Biological research in space and its significance for closed ecological systems.

Paper presented at the Second Meeting of the U.S./U.S.S.R. Working Group on Space Biology and Medicine, 16-24 September, 1988.

[22 references; 3 in English]

Author's Affiliation: Institute of Biomedical Problems, U.S.S.R. Ministry of Health, Moscow

Life Support Systems, CELSS, Population Level Effects, Ecosystems

Microbiology, Botany, Algae, *Chlorella*

Space Flight

Abstract: The author reviews the past 10 years of research on human biological support systems. She argues that at the current stage of development, when much is already understood about the underlying principles and dynamics of such systems, it is critical that systems developed in ground-based simulations be tested in space. Space flight might reveal the need for adjustments in a system developed on the ground, and results obtained on the ground might not be applicable to space.

Since they were obtained (with isolated exceptions) at the level of the individual organism, the experimental results in gravitational biology obtained during the last 30 years of the space era, are not sufficient for determining whether a CELSS can operate under actual conditions of space flight. The key factors for stable functioning of a CELSS occur at levels of biological organization above that of the individual. Although the effects of weightlessness at these levels may differ from effects at the level of the individual organism and may be realized through different mechanisms, they have not been studied.

Meleshko thus calls for a new stage in the strategy for understanding the biological influence of gravity — the study of the effects of gravity at the population, biocenosis (community), and ecosystem levels. This new stage would extend the study of the effects of weightlessness on fundamental biological structures and the reactions of individual functional systems to the study of the long-term fate of these reactions, which depends on the state of the population, biocenosis, and system as a whole.

It is important to acknowledge here that the biological role of gravity need not be the same at every level. Weightlessness may have different effects at different levels of biological organization (from the cell to the ecosystem) and its effects may be realized through different mechanisms. The levels Meleshko proposes to consider are:

1. The primary biological role — the direct effect of weightlessness on the fundamental biological processes in the cell, genetic structures, and morphogenetic processes;
2. The secondary role — effects mediated by gravity-dependent physiological functions (circulation, anti-gravity and motor functions, fluid-electrolyte metabolism, and others) within an organism. This is an indirect path through which weightlessness affects the organism, mediated by changes in the conditions under which the gravity-dependent functions of the organism are realized;

3. Nonbiological (physical and technical) — mediated through gravity-dependent environmental factors and the interactions between the organism and the environment (position in space, distribution of liquid and gas, sedimentation, mass and energy transfer, distribution of trophic resources in the environment, etc.).

The first two types of effects must be mediated by effects at the organism level if they are to impact a higher level of biological organization, while the third type of effect may act directly on any level of biological organization. Such effects are most likely to arise at the population and system levels, in which organisms function in dense populations and undergo environmental pressure due to competition and intrapopulation gradients of environmental factors. Such effects may lead to disruption of the interactions in the "organism-environment" system.

Meleshko argue that it is possible that the frequent contradictions among results obtained in the area of gravitational biology may be due to failure to consider the paths and possible mechanisms for the effects of gravity in specific instances.

The level of the individual organism encompasses all stages in the life of the individual, from fertilization of egg cells to the mature organism that produces the next generation. Within the organism, there are various possible points of impingement for the effects of weightlessness, from elementary cellular structures and functions, including the genetic apparatus, to the complex gravity-dependent functional systems of higher vertebrates. All these compose the ontogenetic level — the basic level at which the effects of gravity impinge in all their manifestations

However, isolated individuals can exist only in the laboratory. In nature and the simulated CELSS ecosystems, individuals exist only within populations and biocenoses. From this it follows that the effects of weightlessness that are realized at the level of the organism may lead to changes at all the higher levels of biological organization. Research on the effects of weightlessness, for example, at the population level, for several generations of individuals, enables conclusions to be drawn concerning the ecological significance of changes manifested at the elementary sublevels of the organism. Such changes may not be realized at higher levels of organization because they may be compensated for by genetic, morphogenetic, or physiological regulation at the level of the organism, or by the mechanisms of population, interpopulation or community regulation that protect every ecosystem in nature. Thus, the ecological significance of changes occurring at the organismic level must be evaluated at the higher levels of biological organization. Factors that have essentially no effect on the relative viability of the individual within a population may be of major importance at the population level. Without studying these "higher" criteria for evaluating the effects of weightlessness, it is not possible to make a final judgment about the true role of weightlessness on the fundamental units of an actual CELSS — populations and communities.

The next step in the research the author describes was to attempt to use specific experimental subjects, one-celled algae — the simplest possible biological systems, to illustrate these ideas about the pathways of influence, mechanisms of effects, and possible points of impingement of weightlessness. Such simple systems are suitable subjects because they are free from the confounding effects of regulatory physiological mechanisms characteristic of higher organisms. In addition, study of the effects of weightlessness on these subjects is of great practical interest with regard to implementation of human-rated CELSS, since these microorganisms are capable of serving many related functions therein. It is also notable that algae, particularly *Chlorella*, have been thoroughly studied in weightlessness on various spacecraft, starting with the launching of the first artificial satellites. While there is substantial lack of agreement among the large quantity of experimental data obtained on *Chlorella* in space, it may nonetheless be concluded that weightlessness has no direct effects on the major fundamental processes

(metabolism, growth, development, reproduction) of one-celled organisms. These results, obtained on the molecular-genetic and ontogenetic levels, can also be applied to the cellular level, since *Chlorella* is a one-celled organism. The disagreement among the results of different experiments on these subjects does not detract from this conclusion. If weightlessness did in principle prevent the functioning of the major vital processes in the cell, it would not be possible to obtain any positive results. Thus weightlessness imposes no such generic prohibitions on these organisms.

However this does not mean that the issue is closed and the suitability of *Chlorella* for CELSS in spacecraft has been proven. This conclusion cannot be based solely on the absence of primary effects of weightlessness, but must be confirmed at higher levels of biological organization. Important here is the possibility that the primary effects of weightlessness, at first barely detectable, may accumulate over a number of generations. In nature, it is common to find that changes that are below the threshold of individual physiological reactions manifest themselves in a number of generations at the level of the population and lead to a change in population characteristics. From an evolutionary perspective, such changes may be even more significant than changes at the level of the organism.

The experimental data discussed in this paper were obtained through study of the effects of weightlessness on one-celled algae at higher levels of biological organization: the population, biocenosis, and ecosystem. Subjects were cultures of algae, containing up to 10^8 kl/ml. This number of individuals in actively growing cultures can be considered a closed population. Algae populations were grown autonomously and in communities.

Two series of experiments were performed: the first used populations of *Chlorella* cultivated in sterile conditions using heterotrophic nutrition; the second used populations cultivated along with concomitant microflora and fish in the "Aquarium" community. In the first series, five experiments lasting from 4 to 18 days, were conducted; while in the second there were two experiments, 13 and 9 days in duration.

Methodology. In the first series of experiments, algae were exposed in the "IFS-2" (inoculation-fixing system, model 2) device. This device consists of a shell containing a hermetically sealed chamber, the interior surface of which has a hydrophilic coating. Fifty ml of nutrient medium and four ampoules of algae (with 2 ml in each) were placed in the chamber. The algae were inoculated on board the "Salyut" space station by the cosmonauts, who broke one or several of the ampoules with a special tool so as not to disturb the hermetic seal of the chamber. The remaining ampoules were exposed to space while still sealed, with the algae in an inactive state. The algae were cultivated heterotrophically, i.e., the instrument did not have an illumination system.

In the second series of experiments, the algae were cultivated in the "Aquarium" device under autotrophic conditions in a community with concomitant microflora and fish *Poecilia reticulata* pet.. The aquarium was completely isolated from the environment, had an autonomous illumination system (a fluorescent light with electric power of 8 W), and contained 2.5 l water and 0.35 l air. The illuminated surface was 0.018 m^2 in area and the darkness:light ratio was 16:8.

The ground control conditions were run in the first series of experiments in two variants (laboratory and transport) with the exception of experiment 2, in which there were four control groups: two in the "IFS-2" device and two in a "cuvette" device specially developed to increase comparability of control conditions. In the second series of experiments, there were three control groups: laboratory, transport, and synchronous.

The experiments used the one-celled green algae *Chlorella vulg.*, strain LARG-1.

LIFE SUPPORT SYSTEMS

Dependent variables in the experiment were growth; development; multiplication; and the state of the population — density, productivity, age structure, and pigment concentration.

All experiments revealed good algae growth. Tables 1 and 2 cite the major growth characteristics of algae in weightlessness for experimental series 1 and 2. In the isolated growth experiments of the first series, the number of cells in the population increased by an order of three compared to baseline. Number of reduplications per experiment fluctuated from 3 to 10, while number of generations ranged from 1.5 to 5.0. The maximum number of reduplications occurred in the experiment with the minimal initial suspension density (series 1), because the terminal density of the suspension was limited by the supply of oxygen in the device. In the second series of experiments, increase in the algae population was slower, since it was related to the metabolism of the fish and limited by the carbon dioxide resulting from their respiration. Here there were 5 reduplications and 2.5 generations of algae per experiment. The functional regimen of the community in the "Aquarium" device was structured in such a way that during the light period the algae absorbed all the carbon dioxide accumulating during the dark period as a result of the respiration of the whole community and the gas exchange of the fish during the light period.

Table 1: Characteristics of growth and development of algae in weightlessness and ground-based control groups in experiments in the first series

Flight duration days	Group	Density, million kl/ml		Number of:	
		initial.	final	reduplications	generations
6	Flight	1.4	89.0	6.0	3.0
	Control	1.2	105.0	6.4	3.2
9	Flight	1.7	103.0	6.0	3.0
	Control	1.7	88.5	6.0	3.0
18	Flight	1.9	140.0	6.0	3.0
	Control	1.9	152.0	6.4	3.2
15	Flight	7.5	184.0	4.8	2.4
	Control	7.5	200.0	4.8	2.4
15	Flight	0.2	201.0	10.0	5.0
	Control	0.2	183.0	9.8	4.9

Table 2: Characteristics of the growth and development of algae in weightlessness and in ground-based control groups in the second series of experiments

Flight duration,	Group	Density million, ml/kl		Number of	
		Initial	final	Reduplications	generations
13	Flight	0.3	4.8	5.1	2.4
	Control	0.3	4.5	5.0	2.2
9	Flight	0.2	3.0	2.8	1.5
	Control	0.2	3.1	2.8	1.5

The productivity of the algae in weightlessness compared with the ground control group for the first series of experiments is shown in Figure 2. This figure shows that productivity varied with respect to the ground control as a function of the device in which the control group was housed. In series 1, rate of growth of the algae in weightlessness compared to that of the control in the same device was 146%, corresponding to data in the literature indicating accelerated

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growth of bacteria and algae in weightlessness. Analysis of the results of this series of experiments showed that when cultures were grown in the "IFS-2" on the ground, gravity limited them to the bottom surface, while in space, cultures grew on all internal surfaces. The "cuvette" device used in the final control group, had a bottom surface equal to the sum of the IFS-2 surfaces available in space.

This showed that the apparent increase in rate of growth observed in space, which had previously been attributed to the primary biological effects of gravity, was, in this case, actually a manifestation of nonbiological (physical/technological) effects of weightlessness mediated by the gravity-dependent physical factors of the environment. This is of great practical significance, since the creation of biological life support systems using one-celled algae requires the development of an effective technology for their cultivation, which itself is affected by weightlessness. This demonstrates that the development of a biological life support system based on one-celled algae or other biological subjects is an extremely complex problem in biological engineering, requiring a great deal of research by many specialists in different areas.

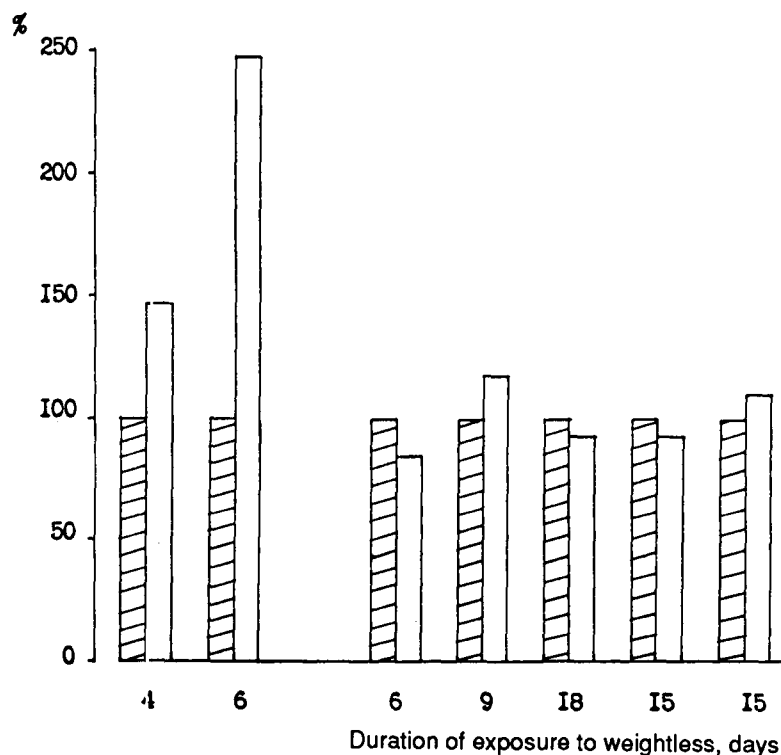


Figure 2: Increase in number of cells in experimental and control conditions
White bars: experimental; Hatched bars: control

In the second series of experiments, the increase in the number of algae cells and dry substance in weightlessness was analogous to that occurring in the ground control conditions, including the synchronous control, which completely reproduced all the algae cultivation conditions as well as transport to the laboratory (Figure 3).

The state of the population of algae in weightlessness for the the first and second series of experiments is described in Tables 3 and 4, respectively. The state of the population was close to the norm. Dead cells were either absent or accounted for less than 1% of the population. The number of cells with decreased viability was 2-8% of the total in different experiments. This value did not depend on duration of the experiment, and showed no significant differences from the ground control. These results imply that environmental conditions in the flight experiments were adequate to the needs of the algae and supported normal growth.

Multiplication of the algae during the experimental period and throughout the life-span of five subsequent generations of individuals was normal in weightlessness. This can be seen in the relative numbers of mother cells in the populations (2-7%), which were the same as that of ground-based controls. Fluctuations in the numbers of cells with autospores in various experiments were associated with the point in the growth curve at which the cultures were analyzed postflight. In the majority of mother cells, there were 4 autospores each; only in a few did the number of autospores reach 12, which was associated with the size of the cells. No disruptions of spore formation were noted.

The cell size parameter also attested to the normal multiplication of *Chlorella* individuals in weightlessness. Distribution of cells on the basis of size in the population of algae fell in the range of cell dimension fluctuations found for the ground control conditions (Figure 4). The majority of individuals (cells) in the population were 3-6 μm in size. The mean cell size for all experiments and variants was 5.0 μm and was stable from experiment to experiment; variance did not exceed 12%.

The age structure of the population of algae grown in weightlessness did not differ from that of the ground control. The ratios among individuals of various physiological ages in all flight variants were characteristic of rapidly growing populations with a preponderance of young photosynthetically active individuals and remained in a fluctuation range characteristic of normally developing populations cultivated in a cumulative regimen on Earth.

The relative number of photosynthetically active cells in the flight populations (first series of experiments) was 71.7%, with a variance of 16.2%. For the control, these parameters were 68.1% and 13%, respectively. Thus, values of this parameter were virtually identical and extremely stable from experiment to experiment and between variants of an experiment. No differences were found in the relative numbers of mother cells and autospores between the flight and control conditions. Differences were found only between individual experiments and were related to differences in duration of cumulative cultivation. The relative number of autospores in the experiments fluctuated within the range of 37-42%, while the number of mother cells varied from 2% to 7%. The results on age structure of populations of *Chlorella* in the flight and ground control conditions for series of experiments are presented in Figures 5 and 6. These results attest to the normal distribution of individuals varying in physiological age in the population of algae and to the identical age structures of the population cultivated in weightlessness and in the ground control condition, with the large body of data obtained in the laboratory on the cumulative cultivation of *Chlorella*.

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Table 3: Status of *Chlorella* population in flight and ground control groups

Flight duration, days	Group	Number of cells		Size of cells, μm	
		dead, %	diminished viability, %	mean	range
6	Flight	0	8.5	5.7	2 - 12
	Control	0	11.8	5.9	2 - 12
4	Flight	0	2.0	4.7	2 - 12
	Control	0	2.5	5.2	2 - 12
9	Flight	0	2.0	5.1	2 - 9
	Control	0	3.0	4.8	2 - 12
18	Flight	0	3.0	5.3	2 - 10
	Control	0	5.2	5.1	2 - 10
15	Flight	1.0	2.0	4.2	2 - 9
	Control	0.5	2.0	4.4	2 - 11
15	Flight	1.0	2.0	4.1	2 - 9
	Control	0	2.0	4.7	2 - 12

Table 4: Status of *Chlorella* population in the "Aquarium" system in flight and ground control groups

Flight duration, days	Group	Number of cells		Size of cells, μm	
		dead, %	diminished viability, %	mean	range
13	Flight	2.0	4.0	4.4	2 - 10
	Control	1.0	2.0	4.8	2 - 10
9	Flight	1.0	3.0	4.5	2 - 10
	Control	0	2.0	4.7	2 - 12

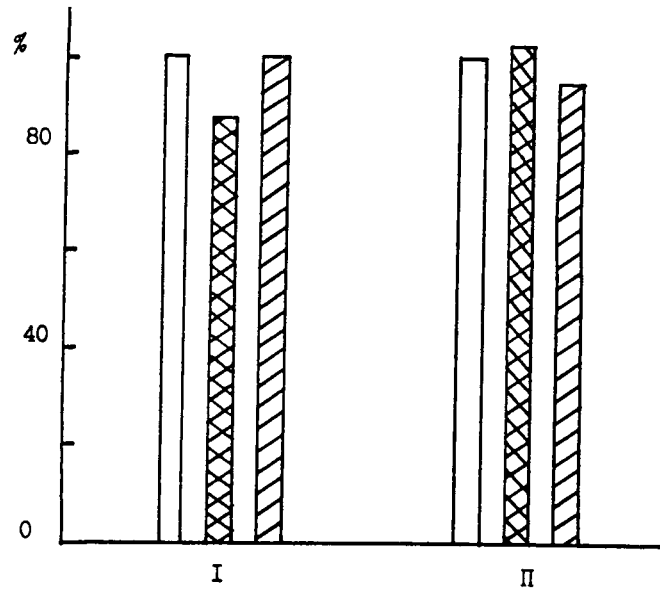


Figure 3: Productivity of algae in flight and control conditions

White bars: experimental; hatched bars - synchronous control; cross-hatched bars - laboratory control

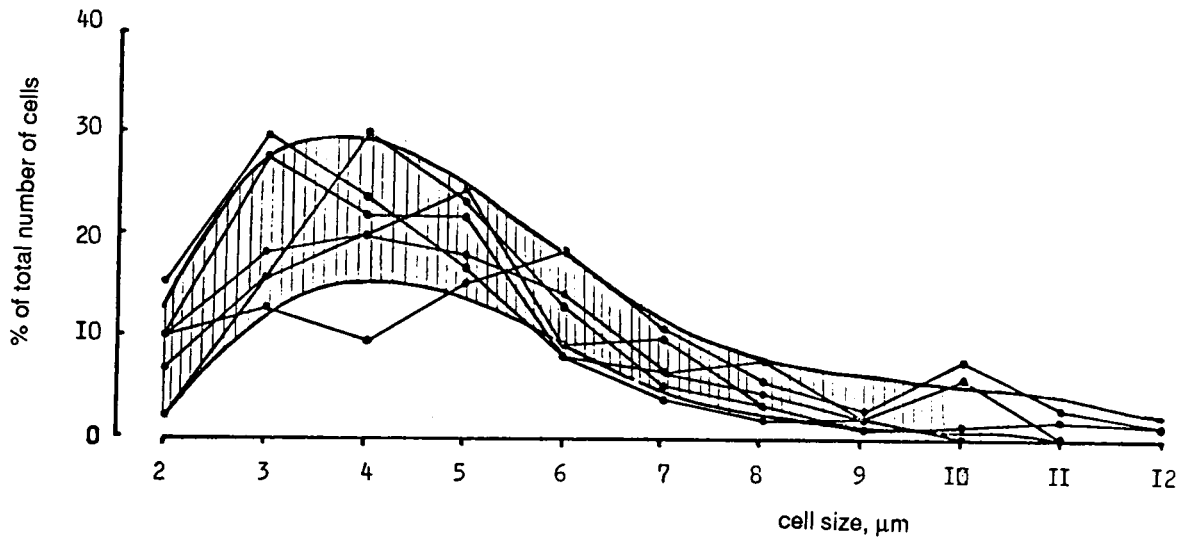


Figure 4: Size distribution of algae cells from flight cultures in "*Chlorella*" experiments (hatched area represents size distribution of control cells)

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Thus, it was found that when high density populations of algae are cultivated autonomously or as components of an ecosystem in weightlessness, growth and development proceeds normally and the optimal relationships are maintained among the individuals in the populations and within the "organism-environment" system. Previous data suggesting that growth and development of algae cells are disrupted in weightlessness were not confirmed by this study of algae in a series of generations and at higher levels of biological organization. The conclusion that there is no primary biological effect of weightlessness may be extended to the highest level of biological organization — that of the system. Algae completely fulfilled their ecological function of supporting gas exchange and environmental conditions of fish in the system ("Aquarium" experiment).

The experiments revealed a statistically reliable decrease in concentration of chlorophyll in all flight cultures of algae. It was established that in the flight variants of the experiments, the chlorophyll contained in the algae cells was reduced by almost half compared to the ground control groups (Table 5). This difference was found both for heterotrophic nutrition and autotrophic nutrition of the algae cultivated under optimal conditions. In the series of experiments with heterotrophic nutrition, the algae demonstrated significant fluctuations in the concentration of chlorophyll in the cells which was not directly associated with other parameters investigated. Under subsequent cultivation in the laboratory with normal illumination, pigment in the algae cells recovered to control level in 12 hours. No remote effects of this phenomenon were detected during subsequent long-term cultivation. Thus changes appeared adaptive rather than pathological. No hypothesis is offered to explain the effect of weightlessness on chlorophyll. However, the author suggests that the effect should be considered as a sign of change in the most important functional system of the plant organisms, the cause and biological significance of which requires further investigation.

Table 5: Concentration of chlorophyll in cells of algae exposed to weightlessness and in ground-based control groups

Experiment No.	Experiment duration, days	Chlorophyll, % dry weight Flight	Control	Cultivation conditions
1	9	0.71	1.20	heterotrophic
2	18	0.78	1.37	"
3	15	1.00	1.61	"
4	15	0.86	1.70	"
5	9	2.70	4.10	autotrophic
6	13	2.60	4.20	"

In conclusion, the author notes that the pathways through which the effects of weightlessness are manifested, the mechanisms of these effects, and the points of impingement turned out to be significantly broader than earlier hypothesized. Even with respect to one-celled algae, where there is no primary biological effect, as confirmed at various levels of biological organization in five successive generations of individuals, there are other indirect ways that the effects of weightlessness are manifest. She argues that to implement a CELSS in weightlessness we need an additional stage of space biological research, focussing on the effects of space flight on the higher superorganismic levels of biological organizations: populations, communities, and simulated ecosystems. Subjects suitable to the initial stages of such research are aquatic ecosystems of the "Aquarium" type of varying structures and degrees of closure of the substance cycles. Such systems do not require complex support equipment and the aquatic living environment simplifies the quantitative study of ecological associations among subjects.

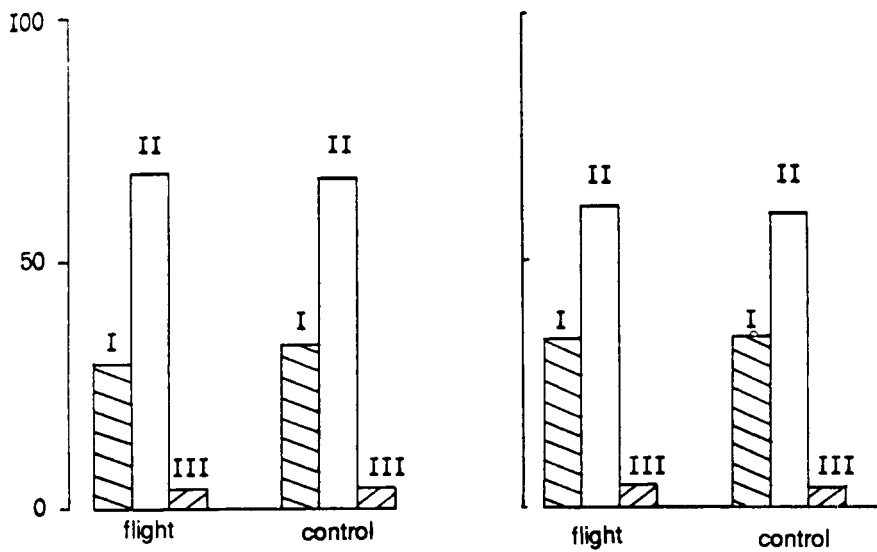


Figure 5: Physiological age distribution of cells
a: in flight; b: subsequent cultivation; I - autospores;
II - photosynthetically active cells; III - mother cells

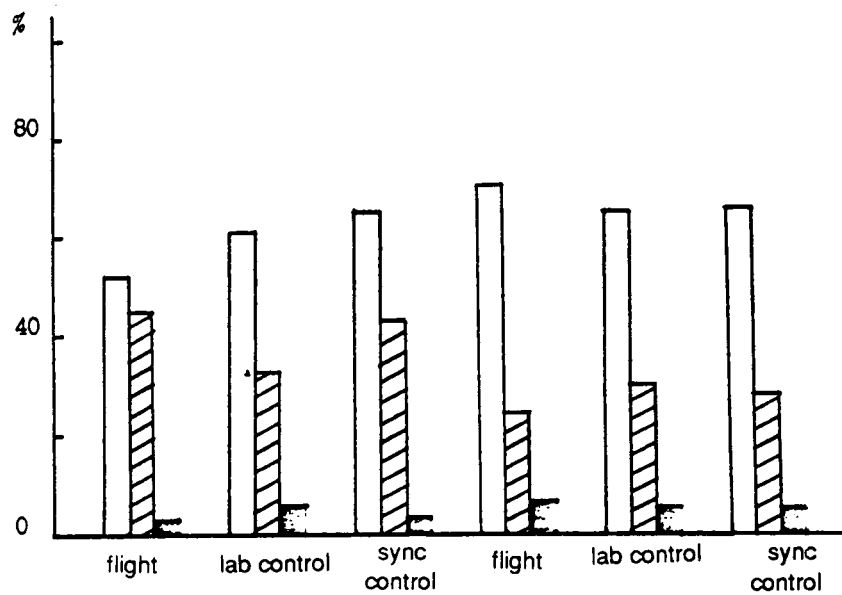


Figure 6: Age structure of algae populations in "Aquarium" experiments.
White bars - photosynthetically active cells; hatched bars - autospores;
shaded bars - mother cells.

MATHEMATICAL MODELING: See Cardiovascular and Respiratory Systems: P962

METABOLISM: See Body Fluids P961; Developmental Biology M143

MICROBIOLOGY: See Exobiology P980; Life Support Systems P981

MUSCULOSKELETAL SYSTEM

(See also: Developmental Biology P974, P976, M143; Reproductive System P973)

PAPERS:

P953(21/89)* Urmanchayeva TG, Eliava VM, Polulyakh YuT.

The effects of long-term hypokinesia on the characteristics of the phasic-tonic motor acts in monkeys.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 46-51; 1988.

[24 references; none in English]

Musculoskeletal System, Gastrocnemius Muscle, Motor Acts, Phasic-Tonic, Fine Motor Skill Monkeys

Hypokinesia, Horizontal, Restraint

Abstract: This study was performed on 7 rhesus macaque monkeys. The animals were taught a fine motor skill while strapped to a "primate chair." The skill was taught using an automated trainer including an actograph (pedal attached to a potentiometer, transforming pressure on the pedal to an electrical signal), a system for delivering fruit juice, and a display with light and sound signals and a control panel. The animals were prevented from visually controlling the position of their feet on the pedal. At a light signal the animal had to depress the pedal three times through plantar flexion to the stopping point in a period of 3 seconds. If this was accomplished, the light went out and a tone was sounded, at which point the animals had to hold the pedal at a point between the two extreme positions for no less than 3 seconds. If successful, the animal was reinforced with juice and the next cycle started. The animals were subjected to hypokinesia after they had attained 80-100% performance on the task. Testing on motor task performance occurred in 4-5 trials during the baseline period, and after 10, 20 and 30 days of horizontal hypokinesia and on days 3, 4, 11, and 14-15 during readaptation. Each trial consisted of 100 start signals. Brain waves were registered on a recording electroencephalograph; times of signal onset and offset and juice delivery were also recorded, as were an actogram for performance of the motor task and an electromyogram of femur and gastrocnemius muscles. Kinematic data were analyzed for the following parameters: duration of phase activity (from moment of onset of the light signal to onset of the sound), period of each phasic movement (from the beginning of plantar flexion to return to initial position), time to attain maximum amplitude of the rapid movement, time to locate the correct placement of the pedal (time elapsed between sound onset and beginning of stable maintenance of the pedal in the required position), and time to return to initial position. The electromyogram was analyzed for bursts of bioelectric activity and maximal amplitude. "Electromagnetic muscle effectiveness" was defined as the ratio of the area of the electromyogram of the gastrocnemius muscle to the area of the mechnogram of plantar flexion. Method of creating horizontal hypokinesia is described as "humane"?? restraint. Student's t was used to test data for significance.

Data on subjects in the baseline period showed that the motor skill had been automated. After 10 days of horizontal hypokinesia, kinematic and bioelectric parameters of the correct movement were, in general, no different from baseline. However, performance was decremented by 42% and time parameters of the motor response increased. Changes in the electromyogram of the gastrocnemius were also clear after 10 days of hypokinesia; duration of activity bursts for the phase movements increased and their amplitudes decreased. Further increase in exposure to hypokinesia further decreased EMG amplitudes. These results are interpreted as suggesting that as treatment progressed, achieving a given force required more time and the

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electromechanical efficiency of gastrocnemius contraction decreased. However, even after 50 days the rapid flexion-extension movements were being performed at 60% accuracy. After 20 days of treatment, maintaining the foot in a given position was accompanied by increased amplitude of bioelectric activity. After 20 and 30 days of exposure to hypokinesia most animals were unable to perform the static component of the task. After longer duration exposure to hypokinesia temporal changes in kinematic parameters altered the pattern of movement, more significantly with the tonic component of the motor skill. The authors attribute much of this effect to disruption of proprioceptive efferent stimulation during hypokinesia (recall that visual control of the muscles was not possible.) Significant recovery could be seen in the tonic component soon after treatment terminated and recovery was virtually complete by the end of week 2. At the same time, certain temporal parameters of the phasic movements (period of phasic movement, period to attain maximum amplitude) were still above baseline after 15 days of recovery. The authors attribute this (as well as increased time for the muscle to return to initial position after the tonic component of the skill) to decrease in rate of contraction of agonist muscles to the required movement. The authors recommend this paradigm for studying the effects of various factors on the motor functions of primates.

Table: Changes in parameters of motor skill performance during an experiment with monkeys

Figure 1: Actogram of performance of a motor skill in the baseline period, and on days 20 and 30 of horizontal hypokinesia

Figure 2: Changes in maximal amplitude and duration of bursts of activity on an electromyogram of the gastrocnemius muscle in performance of phasic movements

Figure 3: Changes in maximal amplitude of an EMG of the gastrocnemius muscle while maintaining the foot in a given position

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P954(21/89)* Shvets VN, Pankova AS, Gol'dovskaya MD, Rustam'yan LA.

Dynamics of immobilization osteoporosis in rats.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 51-55; 1988.

[22 references; 12 in English]

Musculoskeletal System, Osteoporosis, Dynamics, Brachia, Tibia, Femur

Rats, Males

Immobilization, Stress, Adaptation

Abstract: Male Wistar, rats weighing 250-270 g, were placed in immobilization cages for 7, 15, 35, and 60 days. At the end of each period, 10 animals were sacrificed and bones isolated from various parts of their skeleton (tibia, femur, brachia, lumbar vertebra, sternum and iliac). The same bones were removed from control animals at the same periods ($n=7$). An additional 8 rats were studied 15 days after cessation of a 60 day period of hypokinesia. Bones were fixed, decalcified, and poured into histoplast. Frontal histological sections (5-7 μ m thick) passing through the center of the bone were prepared and stained with hematoxylin and eosin or toluidine blue. Histomorphometric analyses were performed using a grid. Three-dimensional density of spongy bone (percent of volume occupied by trabeculae, excluding the medullar and vascular spaces) was measured throughout the metaphysis of the long bones, spinal cord, sternum, and bones of the pelvis as an indicator of the total mass of spongy bone. Three-dimensional density of spongy bone in the area of the primary spongiosa (mass of trabeculae, below the zone of hypertrophied cartilaginous cells of the epiphysial growth layer) was measured as an indicator of mass of the metabolic portion of spongy bone. The breadth of the epiphysial growth layer and its individual zones (proliferative, hypertrophied) were also measured. The state of this layer is an indicator of bone growth parameters, and of proliferation and maturing of chondrocytes. Numbers of osteoclasts and osteoblasts were estimated in the primary spongiosa of various bones. Cells were counted in 5 visual fields at magnification of 400. Student's t was used to test significance of data.

During the first 2 weeks of hypokinesia the density of all spongy bone in the metaphysis of long bones decreased in both the hind and fore limbs. Subsequently this parameter reached a new stable level. Fifteen days after termination of 60 days of hypokinesia this parameter had returned to control level only in the brachia, but was still at the level it had been on day 7 of treatment in the tibia and femur. Decrease in this parameter appeared to be primarily attributable to inhibition of the process of cartilage formation. The maximum decrease in cartilage was noted on day 7, after which the parameter stabilized at a new low level. Thinning of spongy bone was much less pronounced in bones of the trunk and pelvis. The authors conclude that the pattern of osteoporosis development is similar in all bones under exposure to hypokinesia, while severity varies as a function of the functional loading on the bone.

Decrease in spongy bone density was closely associated with changes in bone cells. This was especially clear on day 7 of hypokinesia, when number of osteoblasts had decreased exponentially, while the number of osteoclasts increased. Number of osteoclasts began to decrease only after 2 weeks of hypokinesia; after treatment termination, recovery of osteoblasts was faster than that of osteoclasts. The authors attribute the rapid loss of bone tissue during the initial 2 weeks of treatment to a stress response, mediated by increased level of corticosteroid hormones. Initial increases in osteoclasts may be due to an elevated level of parathyroid hormone. Stabilization of parameters after 15 days of hypokinesia is attributed to the animals' adaptation to the new conditions. While during the first 2 weeks of hypokinesia osteoporosis develops as a result of temporary increased resorption and attenuated apposition of new bone, during the following period both new formation and resorption decrease proportionately and a new lower stable level (steady state) is maintained. The authors argue

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that the two-phase pattern of changes in bone tissue in response to hypokinesia is a universal reaction allowing an organism to adapt to new conditions of existence through survival of stress.

Figure 1: Changes in density of all spongy bone in the metaphysis of the brachia, tibia, and femur bones.

Figure 2: Change in the density of all spongy bone in the metaphysis of the tibia bone

Figure 3: Change in the density of all spongy bone in the body of the vertebrae, sternum and iliac bone

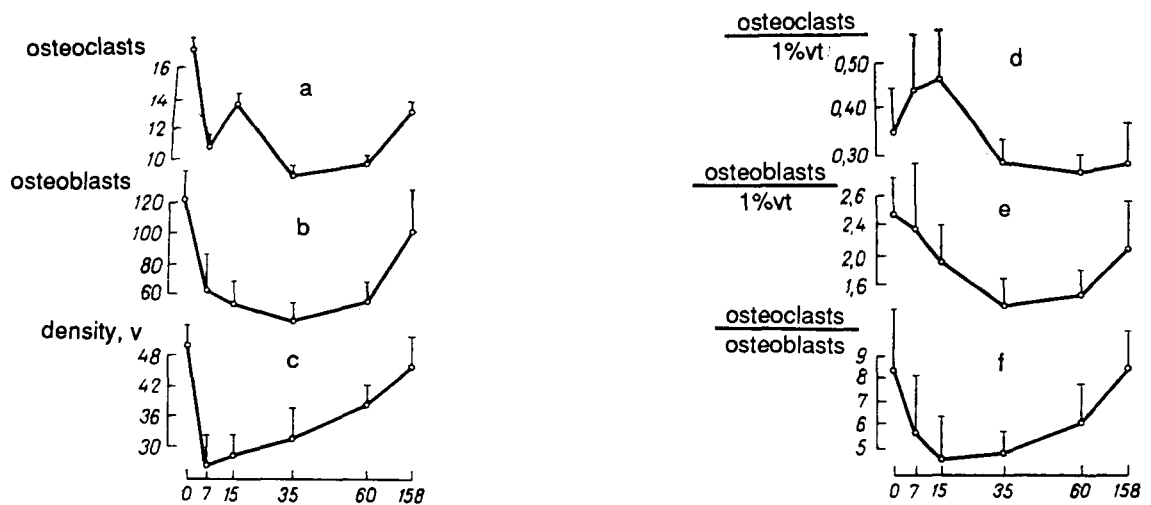


Figure 4: Change in the number of osteoclasts (a), osteoblasts (b), and three-dimensional density of spongy bone (c) in the zone of the primary spongiosa of the tibia bone and also the number of osteoclasts (d) and osteoblasts (e) per 1% density of bone.

Abscissa: day of exposure; ordinate: numerical value of parameters

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P977(21/89) Skuratova SA, Oganov VS, Murashko LM, Shirvinskaya MA (USSR).

Postnatal differentiation of skeletal muscles.

In: M143(21/89) Gazenko O.G. (editor) *Ontogenez mlekopitayushchikh v nevesomosti [Ontogeny of Mammals in Weightlessness]*

Moscow: Nauka; 1988; pages 88-97..

Developmental Biology, Postnatal Development, Musculoskeletal System,
Skeletal Muscles, Differentiation
Rats, Neonates
Space Flight, COSMOS-1514

Abstract: Female rats exposed to weightlessness during pregnancy displayed changes in the mass, functional properties, and metabolism of skeletal muscles. However, the study of postnatal development of skeletal muscles in animals developing after prenatal exposure to weightlessness is of even greater interest. Animals of the flight group, and vivarium and synchronous control groups were sacrificed at ages of 15, 30, and 100 days, and the muscles of the hind (soleus /SM/, lateral and medial heads of the gastrocnemius /LHG, MHG/, plantar (PM), and musculus extensor digitorum longus /LED/) and fore legs (medial head of the triceps /MHT/ and brachial /BM/ muscles) were isolated. Absolute and relative (% of body weight) muscle weight were measured. A variant of Szent-Gyorgi's method was used to investigate the contractile characteristics of glycerinized muscle fibers. In each muscle 20-35 bundles of fibers 200-500 μ m in diameter were isolated. Maximum amplitude of isometric contractions, of preparations was measured and contractile (per 1 mm² area of a cross section) and impulse force of preparations were recorded to derive work capacity (area under the curve of a contraction mechanogram). Maximum rate of development of contraction on a linear portion of the mechanogram (in the interval 0.2-0.6 of maximum amplitude) was also determined.

The weight of all the muscles studied increased significantly as the animals matured (Table 27). For the majority of muscles, the increase in weight was parallel to increases in size and body weight of the animals; as a result, the relative weight of the majority of muscles remained virtually the same for all the ages studied. No significant differences between animals developing in weightlessness and control animals were observed on days 15, 30, and 100. The exception to this was an increase in the weight of the LED and both heads of the gastrocnemius muscle in experimental rats on day 15 of their lives, an increase in weight of SM and LED on day 30 and an increase in MHT on day 100 in this same group.

The maximum force developed by muscle fibers on contraction in an isometric mode was twice as great in 30-day-old animals as in 15-day-old ones for the MHT, SM, LHG, MHG, and PM; 1.5 times as great for the LED; and virtually identical for the BM (Table 28). The strength characteristics of muscle contractions of 100-day-old animals did not differ from those of 30-day-olds. At no time were statistically significant differences between the flight and the control groups found in isometric contractions of skeletal muscle fibers.

The maximum rate of contraction of muscle fibers was virtually identical in 15- and 30-day-old rats and more than doubled by 100 days (Table 29). In flight animals, there was a reliable increase in maximum rate of contraction of LED fibers on day 15 and in SM and BM fibers on day 30, and also an increase in this parameter in SM on day 100. No other significant intergroup differences were noted.

The work capacity of muscle fibers in 30-day-old rats was half of that of 15-day-olds, but there were no significant intergroup differences in this parameter, with the exception of a decrease in the SM on days 15 and 100 in flight animals compared to analogous controls (Table 30). It is noteworthy that the work capacity of the fast twitch muscle (BM and LED) showed a

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general tendency to decline with age in all groups of subjects. In contrast, the work capacity of the SM increased with age to almost double its initial value.

Analysis of this data supports the assertion that, in general, changes in the physiological characteristics of muscle occurring in all groups from days 15 to 100 of their lives reflect the normal development of contractile functions and associated metabolic specialization of fibers. These results are consistent with other data in the literature.

Neonate rats do not display great differences in the speed of contraction of future fast and slow twitch muscles. In future fast twitch muscles (LED), contractile speed progressively increases for the first 2.5-3 months, after which it levels off in adult rats to approximately three times higher than that of the slow SM. The speed properties of slow muscles are marked by acceleration followed by a deceleration, or a monotonic acceleration (slower than for the LED) which also ceases during the period of sexual maturity.

Special investigations were undertaken of the dynamics of changes in strength and speed of muscle fibers during the first 40 days of life. Figures 34 and 35 show a clear difference in the development of the contractile properties of fibers of fast and slow twitch muscles. At the same time, the general tendency and ratio of speed properties of LED and SM fibers do not differ from those described for preparations of whole muscles during this period.

These research results show no signs of gross disturbances in the development of the contractile characteristics of muscle fibers in offspring of animals of the flight group. Moreover, the dynamics of changes in strength and speed of LED and SM fibers and the ratio between them before day 100 of life, and also the differences in patterns of change in their work capacity attest to a longer period of development for the slow SM when early postnatal ontogeny occurs in a gravitational field. Decrease in work capacity of LED fibers before day 100 of life, and the contrasting increase in the SM, are in good agreement with the restructuring of the ratios of fast glycolytic, fast oxidative, and slow oxidative fibers in these muscles during the period from weeks 3 to 26 of development .

The current generally accepted idea is that the development of cells from determination to full maturity can be viewed as a sequence of qualitative and quantitative changes in the synthesis of protein macromolecules. In particular, it has been established that during embryogenesis the population of myosins is replaced at least twice — first, in the fusion of myoblasts in myotubes and subsequently during the shift to postnatal ontogeny. In the myogenic cells of embryos, the first reprogramming of the synthesis of myosins occurs during the beginning of terminal differentiation, when there is a sharp increase in the coordinated synthesis of contractile proteins in association with innervation of future muscle fibers. The second reprogramming is associated with the replacement of polyaxonal (postneuronal) innervation of muscles by monoaxonal innervation in postembryogenesis, predominantly caused by exogenous factors.

The results cited above do not provide a basis for postulating the presence of significant changes in pre- and postnatal differentiation of the skeletal muscles studied.

Juxtaposition of the results from animals of the flight group with parameters of the control group and also with the preflight data collected from a baseline control allow us to conclude that animals spending a portion of their prenatal period under conditions of weightlessness do not display gross deviations from the norm in the developmental dynamics of contractile properties of muscle fibers during the postnatal period up to the age of 3 months. The slight differences between the experimental and control groups discussed above were not systematic in nature and were observed only at isolated time periods. It is interesting to note that virtually all instances of differences between the experimental and control animals, involved increases, rather than decreases in the weight and strength characteristics of the muscles in flight animals.

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Table 27: Weight of skeletal muscles of neonate rats in postnatal ontogeny

Age, days	Grp	Muscle weight, mg						
		BM	LED	MHT	SM	MHG	LHG	PM
15	F	18.5±0.9	10.7±0.5 pv,s<0.05	23.0±1.2	8.75±0.3	28.7±2.8 pv,s<0.05	33.6±2.9	10.8±1.5
	SC	18.0±0.9	7.3±0.8 pv<0.05	23.4±0.9	8.0±0.3 pv<0.05	23.36±1.11	31.1±1.0	11.6±0.7
	VC	18.8±0.8	9.0±0.2	22.8±0.7	9.2±0.3	20.2±1.97	28.3±2.2	12.3±0.8
30	F	66.2±2.7	47.1±2.5 pv<0.05	68.5±6.2	43.2±4.2 (sic.)	17.1±10.8	215.0±19.2	71.2±5.5
	SC	71.5±2.3	42.0±1.3	67.2±3.9	37.4±1.0	177.0±12.8	216.5±9.8	70.7±3.5
	VC	64.6±4.8	40.9±2.4	61.5±2.9	37.0±2.1	153.5±14.4	189.6±13.3	62.2±4.5
100	F	229.0±7.3	188.2±3.1 ps<0.05	202.5±8.7 pv<0.01 ps<0.05	151.5±3.9 ps<0.05	767.5±23.7	1005.±37. ps<0.05	351.2±16.7 ps<0.05
	SC	212.3±10.1	158.5±7.6	159.9±11	135.1±5.9 pv<0.05	712.0±29.5	912±22.8	292.0±9.6 pv=0.05
	VC	214.8±7.1	176.2±5.5	174.2±3.5	153.6±6.2	740.0±24.3	964±18.5	326.5±15.2

Table 28: Maximal force (Pm,H.mm 2·10⁻¹) of muscle fibers of rats born after a 5-day space flight

Group	BM	LED	MHT	Muscles			LHG	PM
				SM	MHG			
					15 days			
F	2.41±0.14 ps<0.05	1.63±0.12	1.23±0.08	1.21±0.10	1.17±0.12	1.10±0.10	0.82±0.15 pv<0.05	
SC	1.99±0.88 pv<0.05	1.34±0.14	1.20±0.39	1.11±0.04	1.30±0.33	1.28±0.12	1.04±0.21	
VC	2.54±0.15	1.76±0.32	1.20±0.03	1.42±0.17	1.49±0.17	1.21±0.68	1.23±0.06	
30 days								
F	3.10±0.10	3.05±0.30	3.23±0.24 ps<0.01	2.92±0.31	3.41±0.25	3.22±0.20	2.22±0.26	
SC	3.19±0.25	3.13±0.44	2.61±0.05	2.74±0.13 pv<0.05	2.8±0.26	3.01±0.15	2.97±0.16	
VC	2.85±0.22	2.89±0.34	2.98±0.34	3.22±0.15	3.71±0.45	3.12±0.61	2.42±1.65	
100 days								
F	3.05±0.30	2.69±0.12	3.38±0.47	3.14±0.08				
SC	3.01±0.39	2.51±0.12	2.75±0.31	3.65±0.20				
VC	2.74±0.38	2.76±0.27	2.91±0.20	3.59±0.28				

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Table 29: Maximal speed (Vm,mg.sec-1) of contraction of muscle fibers of rats born after a 5-day space flight

Gp	BM	LED	MHT	SM 15 days	MHG	LHG	PM
F	43.84±3.76	27.43±0.46 ps<0.01 pv<0.05	17.20±1.69 ps<0.01 pv=0.05	11.59±1.60	29.67±2.24	26.33±2.03	19.88±1.93 ps=0.05 pv=0.05
SC	39.03±3.07	20.71±0.96	25.55±1.28	13.29±0.39	32.44±2.57	29.92±2.14	27.06±3.41
VC	38.57±1.79	23.94±1.65	22.78±2.40	13.75±0.74	30.40±2.02	27.70±1.85	25.21±1.71
30 days							
F	23.77±1.78 ps<0.05 pv<0.95	21.62±1.20	26.27±0.92	13.63±0.75 ps<0.05 pv=0.05	27.51±2.07	30.48±1.96	30.47±0.68 ps<0.05
SC	31.78±3.01	24.26±2.01	25.87±1.09	15.42±0.41	30.55±3.26	29.18±1.37	35.28±1.40
VC	30.35±2.92	25.49±3.24	27.45±1.50	15.81±0.79	29.02±1.65	28.47±1.44	33.03±2.79
100 days							
F	69.77±4.35	78.21±3.47	77.50±2.41	59.47±7.08			
SC	67.61±9.10	78.32±3.36	66.72±5.31	49.74±6.05			
VC	69.68±6.35	81.80±7.56	64.83±5.91	43.40±4.02			

Table 30: Impulse force (S, n·sec.10⁻⁴) of muscle fibers of rats born after a 5- day space flight

Gp	BM	LED	Muscles		MHG	LHG	PM
			MHT	SM			
15 days							
F	8.68±0.84	5.38±0.44	4.93±0.46	3.79±0.32 pv<.05	6.45±0.57 pv<0.05	6.92±0.29 ps<0.05	6.92±0.50
SC	9.64±0.25	4.56±0.25 pv<0.05	5.05±0.47	4.46±0.40	8.04±0.98	8.24±0.46 pv=0.05	7.81±1.30
VC	9.03±0.44	5.32±0.22	4.83±0.37	5.12±0.40	7.72±0.26	.21±0.25	7.40±0.76
30 days							
F	3.95±0.63	1.98±0.20	3.07±0.11	2.91±0.37	3.69±0.38 ps<0.05	3.72±0.53	2.89±0.55
SC	4.42±0.67	2.34±0.36	3.32±0.30	2.83±0.25	2.83±0.21	3.69±0.15	3.32±0.29
VC	3.75±0.30	2.08±0.33	3.53±0.35	3.21±0.22	3.26±0.16	3.35±0.23	3.69±0.15
100 days							
F	4.46±0.45	4.41±0.37	6.87±0.61 ps<0.001 pv<0.01	6.24±0.50			
SC	4.69±0.61	4.58±0.26	4.00±0.25	6.33±0.71			
VC	3.81±0.45	3.42±0.50	4.40±0.39	7.85±0.49			

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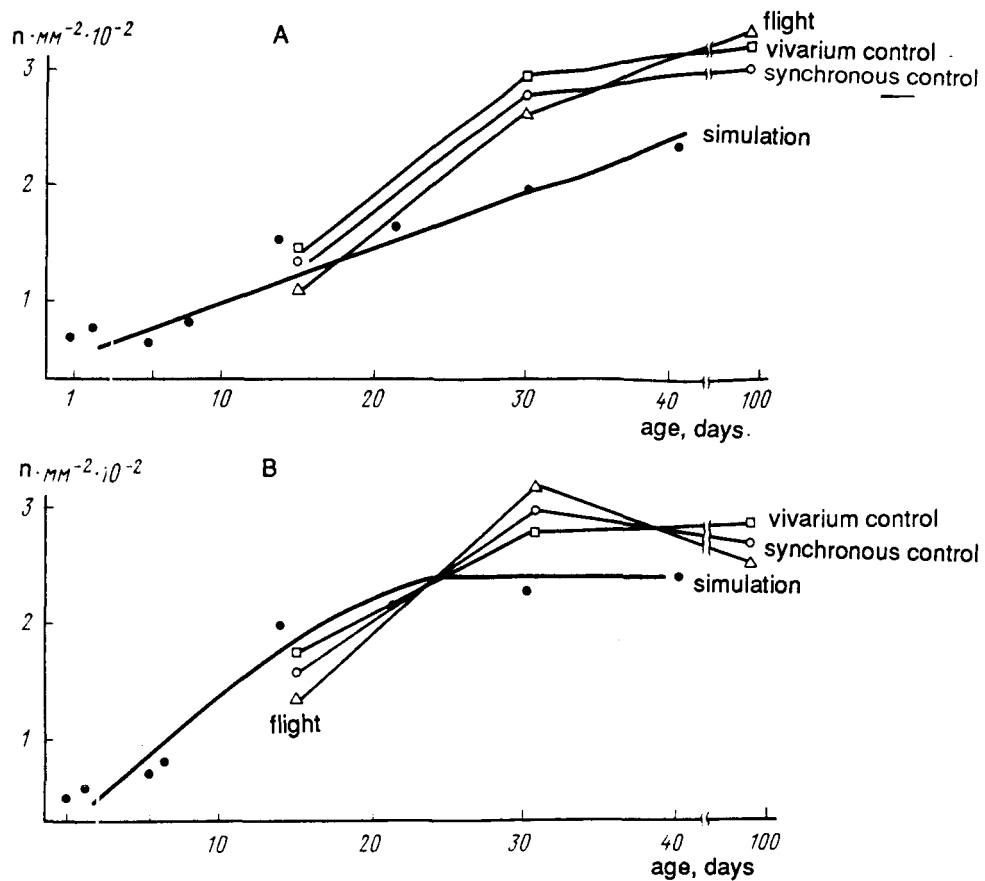


Figure 34: Changes over time in force of contraction ($n \cdot mm^{-2} \cdot 10^{-2}$) of fibers of skeletal muscles in postnatal ontogeny in the offspring of female rats exposed to space on a biosatellite, as compared to the results of a ground-based simulation experiment

A - soleus muscle; B - musculus extensor digitorum longus;

S - simulation experiment.

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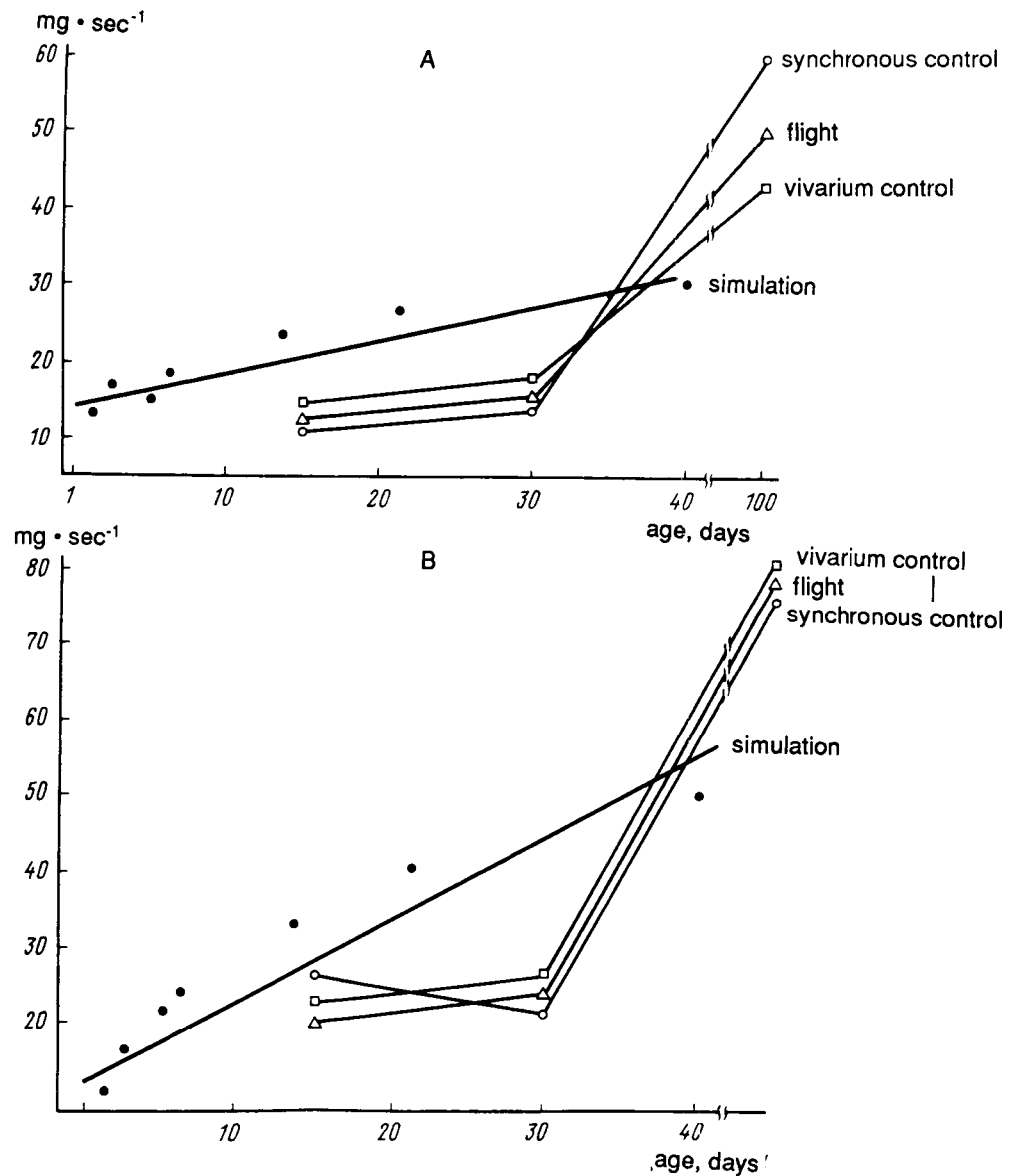


Figure 35: Changes over time in rate of contraction (mg·sec⁻¹) of fibers of skeletal muscles in postnatal ontogeny of animals spending a portion of the prenatal period in space flight, compared to results of a ground based simulation experiment. (For key: see Figure 34)

NEUROPHYSIOLOGY

(See also: Developmental Biology: P976, M143; Habitability and Environment Effects P959; Perception P948; Psychology P978)

PAPERS:

P966(21/89)* Petrova TV, Bobrovnikskiy IP.

The physiological role and significance of prostaglandins in physiological response to exposure to adverse environmental factors.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 6-13; 1988.

[108 references; 54 in English]

Neurophysiology, Prostaglandins, Metabolism, Cardiovascular and Respiratory System
Review Paper

Adaptation, Adverse Environmental Factors; Space Flight, Soyuz-26, Soyuz-29

Abstract: Prostaglandins have been considered universal regulators of the most diverse vital processes. Typically formed in very small quantities in the body (100 µg/day), prostaglandins do not accumulate, but their concentration in blood increases. As soon as they fulfill their function, prostaglandins decompose rapidly, typically under the influence of prostaglandin dehydrogenases. Products of their peroxidation are renally excreted. Prostaglandin types typically studied are designated (PGA, PGE, PGF, PG, and PGD). Others recently attracting interest are prostacyclin (PG₂), thromboxan (TxA₂), and leukotriene (LT). Prostacyclin is formed in the endothelia and has a particularly strong hypotensive effect on the smooth muscles of blood vessels. In addition, it prevents aggregation of thrombocytes. TxA₂ forms in thrombocytes and is an antagonist of PG₂. LT is the name for the hydroxylating products of arachidonic acid forming in the presence of lipoxygenase. LT is synthesized by leukocytes; there are two groups, one of which (C₄, D₄, E₄) excites neural and smooth muscle cells, while the other intensifies migration of leukocytes in tissues in edema and inflammation. The small bronchioles are particularly sensitive to LT.

PGs are messengers of the third class; their effects are explained by their interaction with specific receptors. Although there is a great deal of literature on prostaglandins much is still unknown about the mechanisms underlying their effects. It is certain, however, that this class of substances plays an important role in the cellular mechanisms regulating the process of adaptation to extreme conditions. The most data concerns hypoxia and ischemia, which are nonspecific components characteristic of all extreme states.

The heightened amount of PG found in ischemic tissue suggests that the accumulation of PG is a mechanism to protect the functional structures from oxygen and substrate deficit. Rats with the greatest amount of PGE in their myocardium show the greatest resistance to pressure overload. Administration of polymer prostaglandin PGBx increases the tolerance of mice for hypoxic hypoxia. Triggering of PG synthesis in hypoxia and ischemia appears to be related to activation of PG-synthase. The mechanism of PG's protective effects are most often considered to be vasodilation, improvement of microcirculation and transport of O₂, and limiting the effects of catecholamines through feedback mechanisms.

The stress response is closely related to synthesis and secretion of PG from various tissues. The influence of PG on effects of catecholamines depends on the quantitative relationships among the various PG forms. The most studied effect is the antistressor effect, which is due to the

depressing effect of PGE on output of mediators from neural synapses and also to inhibition of adenylate cyclases destroying cAMP. Also important is the vasodilating effect of PG. When the balance between PGI_2 and TxA_2 is disturbed, there may be hyperaggregation of blood cells and vascular spasms, both harmful effects of stress. Under chronic stress, imbalance of the PG forms may lead to tissue disease, such as atherosclerosis, or high blood pressure. Changes in this balance have been noted in response to stress. Altered PG balance is also typical of cardiovascular diseases. Mechanisms of the effects of PG on heart disease include disruption of vascular tonus when relationships between PGG_2 and PGH_2 and PGI_2 in the vessel walls change. Another mechanism is the induction of vascular spasms and local aggregation of thrombocytes caused by TxA_2 . In addition, PGs affect the activity of hormonal systems responsible for esterification of cholesterol in the vascular wall.

Aside from changes in PG associated with hypoxia and ischemia, PG imbalance has been associated with erythema after exposure to ultraviolet radiation, ionizing radiation, microwave radiation, thermal burns, vibration, acoustic stimulation, and physical exercise.

A dissertation by E. A. Pavlova examined changes in PG in blood after space flight. It was demonstrated that on day 1 after landing, PGE, PGA, and $\text{PGF}_{2\alpha}$ decreased. It is not stated, but presumably subjects were human. The ratio of $\text{PGF}_{2\alpha}/\text{PGE+A}$ depended on flight duration. After a 96-day flight, this ratio was unchanged, while it increased after a 140-day flight on Soyuz-26 and Soyuz-29. In simulations of weightlessness through immersion and hypokinesia with head-down tilt, the initial increase in all PG groups is followed by their decrease. The readaptation period after 7 days of immersion is characterized by excretion of catecholamines and corticosteroids, increased $\text{PGF}_{2\alpha}$ and marked decrease in PGE and PGA, which in the authors' opinion is a compensatory reaction of the body to orthostatic instability. The results of studying PG after immobilizing of animals are contradictory.

The authors conclude that, judging by data from multiple studies, PGs are one of the most active and universal regulators of metabolism. PGs play a major role in processes of adaptation to effects of extreme factors. The unique regulatory effects of PG are due to the fact that they, unlike the majority of hormones (aside from the steroids) and cyclic nucleotides, can penetrate biological membranes and have effects within the intracellular space as well as outside cells and on their surfaces. The stress reaction is most often associated with activation of the synthesis of the majority of forms of PG, which probably reflects the development of protective and stress-limiting mechanisms. A variety of extreme, premorbid states and diseases are characterized by the presence of an imbalance in the different forms of PG. This suggests that examination of PG forms in the body could be used for diagnostic purposes, while PG and its activators and inhibitors might be used to correct these conditions.

P949(21/89)* Lychakov D.V., Boyadzhieva-Mikhaylova A., Khristov I., Panshchin AN, Yevdokimov II, Markov AA. (U.S.S.R., Bulgaria).

Changes in the otolith apparatus of rats and fish after long-term rotation in hypergravity.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5):27-33; 1988.

[22 references; 11 in English]

Neurophysiology, Vestibular System, Otolith

Rats, Fish

Gravitational Biology, Rotation, Long-Term, Hypergravity

Abstract: This study investigated the state of the otolith membrane after long-term exposure to altered gravity. Subjects were rats and guppies. Teleost fish make very convenient subjects for studies of this kind, since their single crystal otolith can be completely isolated and weighed. In contrast, rats' otolith anatomy make weight a less suitable parameter, so the criterion chosen was the mean size of the otoconia. In normal adult animals, the mean size of the otolith does not change. Rats were rotated at 2 g for 30 days and then their labyrinths were prepared and fixed using procedures not specifically described. The otolith membranes of the utricle and saccule were isolated from the membranous labyrinth, placed on glass, and examined through a light microscope in normal and polarized light. Some of the utricular membranes were destroyed and the otoconia placed on a copper grid in a drop of alcohol and studied through a scanning electron microscope. To study the receptor and support cells of the utricle, the maculae were desiccated and a series of cross sections 10 μm in thickness studied under a light microscope.

In the fish studies a special centrifuge was constructed which allowed the aquarium to be rotated at a speed of 0.71 rotations per second. Within the aquarium the acceleration gradient was 1.8 to 2.2 g. For cleaning and maintenance, the centrifuge was halted for 15-20 minutes 5-6 times a week. Particular care was taken to match all environmental conditions in a control group, since fish otoliths grow throughout life and rate of growth depends on environmental conditions. Guppies used in control and experimental conditions were born on the same day. A vivarium control was also used. Two 4-month long experiments were run. In the first, in both experimental and control conditions, the aquaria were covered with a plastic foam top creating "twilight lighting." In the second condition, the aquarium tops were transparent. After the experimental period the fish were sacrificed and weighed. Their otoliths were removed and washed with distilled water, air dried and weighed in pairs. In the first experiment the otoliths were photographed under a light microscope and their area determined from the resulting images. In the second experiment, the microrelief of the otolith surface was studied using a scanning electron microscope.

Some of the rats in both the experimental and control groups were eliminated due to abscessed otitis. Number of subjects remaining is not specified, but seems to be 4 experimental and 3 control animals. The length of the otoconia of the utricle was somewhat longer in the experimental than in the control group, respectively 10.2 (747 otoconia), and 8.1 μm (664 otoconia). There was a linear correlation between the length and diameter of the otoconia. No qualitative differences were found in the structures of the receptor and supporting cells, nerve endings, or capillaries of the utricle between experimental and control groups. No differences were noted in the membrane of the saccule.

In the fish experiments, the development of the fry was found to be completely normal in both groups. A tendency for the experimental animals to weigh more than controls was noted in the first experiment. Weighing of the otoliths showed that in the first experiment the mean weight was greater in experimental animals. This difference was significant for the saccular otoliths

(t-test, $p < 0.05$). There was a tendency for the saccular otoliths of experimental animals to be heavier in the second experiment. In the experimental group, the ratio of the weight of the saccular to that of the utricular and lagenar otoliths increased by 28 and 13% in experiment one and by 10 and 14% in experiment two. Pressure in the saccular otolith was greater in experimental than control animals, and this could not be attributed to rate of growth. There were some changes in the microrelief of the sulcus of the auditory tube (increase in thickness of prismatic subunits) in the experimental group. The authors call for multifactor structural and functional studies of adaptation of the otolith organs to hypergravity. Morphological data do not allow unambiguous conclusions about the functional significance of changes observed.

Table 1: Major results of experiments with guppies

Figure 1: Otolith membrane of the utricle of an experimental rat

Figure 2: Otolith diameter as a function of its length

Figure 3: Ratio of weight of saccular otolith to weight of utricular otolith as a function of weight of guppy

Figure 4: Saccular otolith of guppies

P967(21/89) Rasulov MM, Kaplan YeYa, Velikaya MV.

Characteristics of neurophysiological changes in response to experimental stress induced by long-term group isolation in rats.

Fiziologicheskii Zhurnal SSSR im. I.M. Sechenova.

LXXIV(8): 1087-1093.

(17 references; 5 in English)

Authors' Affiliation: Institute for Biological Tests of Chemical Compounds, Moscow

Neurophysiology, Limbic Structures, Reproductive System

Rats

Isolation, Sexual Deprivation

Abstract: Research was performed on Wistar rats, aged 6-9 months. Chronic sexual stress had first been induced by placing rats aged 3.5-4 months in a cage divided into sections by a wire grid. One section contained males and the other females. The ensuing sexual deprivation lasting for 3-5 months decreased motor activity, increased rate of assuming arched back and vertical postures and grooming behavior, and displaced diurnal rhythms of activity. Sexually isolated female rats displayed disturbance of the estrual cycle. Intact animals maintained under vivarium conditions since the age of 6-7 months served as controls. After treatment, animals were anesthetized and microelectrodes filled with saline solution were inserted intracellularly and used to record spontaneous activity of individual neurons of limbic structures, over a period of 30 minutes. During this period, interimpulse intervals were determined to accuracy of milliseconds. A total of 1024 values of intervals were stored in a computer for each rat and the extreme values and standard statistics computed. Deviations from standard normal distributions were assessed. Structures studied included the hippocampus, amygdala, and septum.

In all the structures studied statistical parameters of discharge rate were different for experimental and control rats (structures also differed significantly from each other). Experimental rats had an increased number of neurons with polymodal distribution of interimpulse intervals.

Table 1: Changes in major parameters of neuronal activity in structures of the limbic system in rats under conditions of group isolation

Figure 1: Impulse activity of the neurons of the amygdala in rats

P968(21/89) Maksimuk VF, Skoromny NA.

The role of cholinergic mechanisms in changes of the functional activity of the brains of rabbits during motion sickness.

Fiziologicheskii Zhurnal SSSR im. I.M. Sechenova.

LXXIV(8): 1109-1118.

(21 references; 7 in English)

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U.S.S.R. Academy of Sciences, Leningrad

Neurophysiology, Functional Activity, Brain; Cardiovascular and Respiratory Systems, Blood Flow

Rabbits

Vestibular System, Motion Sickness, Countermeasures, Scopolamine

Abstract: Experiments were performed on 65 alert rabbits of both sexes with preliminary implantation of platinum electrodes in the frontal, temporal, and occipital lobes of the cerebral cortex and the confluence of the sinuses of the brain. EKGs were recorded in the cervical and subscapular areas using subcutaneous steel electrodes. During the experiment the rabbits were placed in a special cage with an opening for the head which allowed the subject to be fixed to a swing in a relatively comfortable position. Minute volumes of local and total blood flow were measured using the hydrogen clearance method, and partial oxygen tension was measured polarographically. Bioelectric parameters were recorded through electrocorticography (ECoG) and EKG (from two standard leads) and subjected to statistical processing (analysis of variance). Motion sickness induction involved swinging the animals on a parallel swing with radius of 80 cm, frequency of 30-34 per minute, and amplitude of 90° for 1 hour. Every 5-10 minutes, stimulation stopped for 1-2 minutes so that parameters could be recorded. Scopolamine was injected into the vein of the ear in doses of 0.2 and 0.5 mg/kg 1 minute before swinging began. In the first condition (30 sessions), parameters were measured at rest. In the second condition (26 sessions), changes in parameters during motion sickness induction and for 1 hour afterward were recorded. In the third condition (51 sessions), parameters were measured after administration of scopolamine and no swinging. In the fourth condition, scopolamine was injected (at 0.2 mg/kg for 5 cases and at 0.5 mg/kg for 40) and then motion sickness was induced. Twelve rabbits were subjects in all four conditions. Time interval between successive sickness induction sessions (with and without scopolamine) was 1-2 weeks. The remaining 53 rabbits were assigned to only 1 condition. Changes in parameters were analogous for all rabbits studied.

One hour of motion sickness induction led to marked and persistent changes in all parameters studied. Changes in bioelectric activity in the cerebral cortex preceded changes in blood flow and pO₂. Especially striking was a reliable increase in total bioelectric activity in all cortical structures studied during the first 20-30 minutes of motion sickness induction. After 40-50 minutes of treatment, blood pressure had decreased by a mean of 20% in all animals, gradually returning to normal 10-15 minutes after the procedure was terminated. During the period when blood pressure began to drop, cyclic decreases in total bioelectric activity began to occur in all cortical areas studied. In addition, there was marked restructuring of the frequency components of the ECoG, pathological complexes arose and the level of the "stress rhythm" dropped in the range of 4-7 Hz. Greatest stability was shown in the frontal lobes. Starting from minutes 3-5, local and total blood flow in the brain increased and remained elevated throughout the period. Greatest decreases (to 35% baseline) occurred in the temporal and parietal lobes, at 30-40 minutes. Post-treatment recovery was fastest for the ECoG parameters.

After administration of scopolamine (intravenous 0.5 mg/kg) accompanied by no further treatment, cerebral blood flow decreased in the cortical areas and sinus for a period of 2 hours,

with the most pronounced decrease in minutes 20 and 50 after drug administration. In the frontal lobe, blood flow started to decrease at minute 2 and in the temporal lobe, at minute 30, peaking at minute 40. Reliable decreases began to occur in parietal and total cerebral blood flow starting at minute 20 and peaking between 50-60 minutes. Oxygen tension reliably increased during the first 10 minutes in the frontal and after 20 minutes in the parietal and temporal areas. Subsequent changes were insignificant. Changes in bioelectric activity were marked 1 minute after drug administration. After a brief period (15-45 seconds) desynchronization of ECoG and the amplitude of its fluctuations gradually increased. Gradually, the high frequency fluctuations were synchronized in all leads. Rapid increase in high frequency, low amplitude fluctuations occurred first in the frontal lobe and last in the parietal lobe. These fluctuations peaked 10-15 minutes after drug administration. Total bioelectric activity increased throughout the observation period. Sometimes low and sometimes high frequency components dominated. Slow waves were generally more pronounced throughout the period.

When scopolamine was administered in the higher dose and followed by motion sickness induction, there was a decrease in local and total cerebral blood flow. However, these changes were less marked in the visual cortex. No effects were noted on oxygen tension. Synchronization of bioelectric activity was observed, as it was when the drug was administered without motion sickness. However, increase in high frequency ECoG components dominated at first and generalized spiky fluctuations appeared earlier, gradually decreasing after swinging terminated. Gradual increase in the prominence of synchronized slow waves peaked at 20--30 minutes and then decreased. Total bioelectric activity in all leads increased rapidly in the early minutes of treatment, with the parietal lobe the last to be affected. Unlike the conditions without motion sickness, this activity gradually decreased and was not significantly elevated during two measurement periods.

When the smaller dose of the drug was administered with or without motion sickness induction, changes in local and total cerebral blood flow were analogous to those occurring at the higher dose. However, these effects were less pronounced and occurred somewhat later. In the parietal lobe there was a short-term significant increase in blood flow after administration of the drug and beginning of swinging. Changes in oxygen tension were not significant in either condition in any brain area.

The authors conclude that under the influence of scopolamine during motion sickness induction, activation processes occur more readily (especially in the parietal lobe), while there is decreased periodicity in the rise and fall of total bioelectric activity and smoother decreases in all cortical areas. They argue that these data suggest that rabbits' tolerance of motion sickness induction procedures increases after administration of scopolamine, despite the appearance of certain pathological forms of fluctuation in the ECoG. Generalized activity of the brain structures and earlier inclusion of the motor cortex in the activation process evidently lead to faster triggering of compensatory central regulation systems which, in turn, minimizes motion sickness symptoms. At the same time occurrence of EEG patterns with pathological components testifies that, in spite of the drug, the functional systems of the brain continue to be disrupted when procedures ordinarily inducing motion sickness are applied. Thus the protective effect of scopolamine can be associated with its central cholinergic action, facilitating activation of the cerebral cortex (especially, the somatosensory area) when motion sickness is induced, possibly leading to subsequent hemodynamic changes. The inadequacy of the protective effects of scopolamine in motion sickness may be explained by participation of other mediator systems of the brain in reactions to such stimulation.

Table 1: Changes in local and total cerebral blood flow and pO₂ in the brain in alert rabbits under the influence of scopolamine

Table 2: Changes in local and total blood flow and pO_2 in alert rabbits under the influence of motion sickness and scopolamine

Figure 1: Changes in heart rate of alert rabbits after motion sickness induction and administration of scopolamine

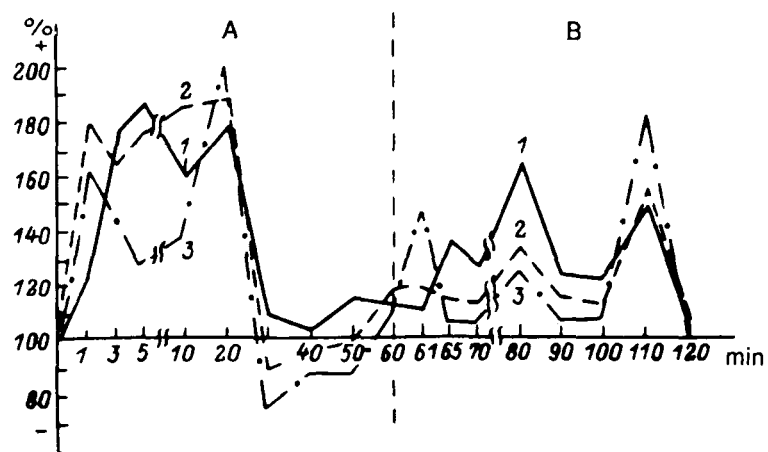


Figure 2: Dynamics of total bioelectric activity of structures of the cerebral cortex of rabbits during motion sickness induction

Ordinate: magnitude of changes in percent of baseline;

Abscissa: time, minutes. Breaks in graph are due to differences in recording intervals in the beginning of the session and after 60 minutes. A - first hour of session, B second hour of session. 1 - lead from the frontal lobe, 2 - temporal lobe, 3 - parietal lobe of the cerebral cortex of rabbits.

Figure 3: Dynamics of total bioelectric activity of structures of the cerebral cortex of rabbits after intravenous administration of scopolamine

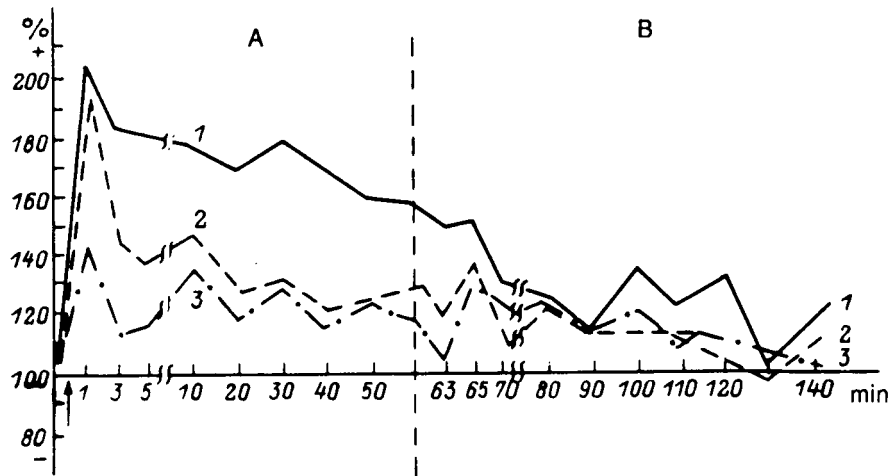


Figure 4: Dynamics of total bioelectric activity of the studied zones of the cerebral cortex after scopolamine administration and motion sickness induction. Key as in Figure 2.

Figure 5: ECoG and EKG patterns of rabbits in experiment with intravenous administration of 0.5 mg/kg scopolamine

Figure 6: Changes in ECoG and EKG of a rabbit in conditions where scopolamine administration was followed by motion sickness induction for 1 hour

OPERATIONAL MEDICINE

PAPERS:

P958(21/89)*Dubinin DM, Polov Ig, Viktorov AN, Shumilina GA.

The condition of the skin in humans housed in a sealed environment.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 68-71; 1988.

[17 references; 5 in English]

Operational Medicine, Skin

Humans, Males

Habitability and Environment Effects, Sealed Living Environment

Abstract: Subjects were healthy males living in a sealed living environment. To establish pathogenic mechanisms of oil-formation and secretion, a group of patients suffering from acne was also studied. The microclimate in the living environment was maintained at an air temperature of $20 \pm 2^{\circ}\text{C}$, and relative humidity of 50 ± 20 [%]. Oxygen was maintained at $21 \pm 2\%$. Air was cleaned and filtered. Subjects ate a standard diet similar to that of cosmonauts consisting of 3000 calories per day. In all conditions, subjects exercised on a bicycle ergometer at 200-250V. Once every 10 days subjects exercised to exhaustion, and in addition exercised daily for 20 minutes performing work of approximately 700 kg·m/min. During their stay in the living quarters subjects showered once in 10 days using 10 liters of water and a cloth permeated with 30 ml of shampoo specially developed for space flight. Hands and face were washed daily using tap water and toilet soap.

Condition of the skin was examined before subjects entered the special living quarters and the day they emerged. Subjects responded to a questionnaire and were clinically examined, and samples of skin oil were collected. The questionnaire asked about past incidence of seborrhea, acne, rash, hair loss, and personal hygiene. The clinical examination concentrated on the face, back and hands. The number and prominence of excretory oil ducts and the number and size of blackheads were noted. Lipids of the skin surface were studied using thin layer and gas-liquid chromatography. Contents of blackheads were also analyzed. Concentrations of phospholipids, cholesterol, free fatty acids, triglycerides, wax, squalene, mono- and diglycerides were identified quantitatively in skin oils. Concentration of individual fatty acids was expressed as a percentage of total fatty acids of the skin. The total saturated and nonsaturated acids with chain length of 16 and 18 atoms of carbon, the total saturated with chain length from 14 to 19 and from 20 to 24 carbon atoms were counted. The coefficient of saturation — the ratio of palmitic acid to palmitoleic acid — was computed. Statistical analyses were performed by computer but are not specified.

The predominant component of blackheads in patients with acne was palmitic acid (35.1%); these patients showed decreased number of fatty acids with chain length of 14-19 on the surface of the skin. In one experimental condition men aged 40-55 spent 30 days in the airtight environment. None of these subjects displayed pathological skin changes before entering the environment. Five days after entering the environment, subjects noted a sensation of oiliness of the skin and itching. These sensations increased during exercise and when environmental temperature increased, but disappeared after showering. Additional products were given them for cleaning their hair without water. After 30 days in the environment, the proportion of saturated acids with chain lengths of 14-19 carbon atoms, including palmitic acid, increased in

virtually all subjects. These changes were accompanied by increased number and size of blackheads. In lipids on all skin surfaces tested, the number of acids with chain length of 16 increased. This was accompanied by a decrease in the saturation coefficient from 1.42 to 1.25, reflecting increased number of anaerobic microflora or increased lipolytic activity. These conditions may increase the risk of skin infections. On the skin of the face the concentration of unsaturated fatty acids with chain length of 14 to 19 increased from 33.2 to 40%.

When subjects between 25 and 35 lived in the same sealed environment for 45 days the most significant skin changes (development of papules and pustules) occurred in one subject who had blackheads before entering the environment, small excretory oil ducts, and an elevated number of comedonogenic acids (saturated with chain length from 14-19 (44.8%; including 4.8% palmitic acid) During the period spent in the environment, these percentages increased slightly; concentration of palmitoleic oil increased by approximately 50%, decreasing the saturation coefficient from 1.7 to 1.2 and attesting to increased lipolytic activity of anaerobic skin microflora.

The authors argue that means of personal hygiene provided in such environments may have to be improved to decrease risk of skin infections. Individual differences must be taken into account when predicting skin infection in sealed environments and prescribing personal hygiene procedures. Risk indicators for skin infection include: large number of oil glands, small oil ducts, and the presence of blackheads. Increased wax and squalene may block ducts, while increased proportion of comedonogenic and palmitic acids may be conducive to development of blackheads. Increased palmitoleic acid may have an irritating effect and lignoceric acid may lead to inflammation. High lipolytic activity of anaerobic microflora is also an adverse factor.

P965(21/89)* Ivanov SG, Bogomazov YeYe.

"Dry" immersion and perspectives for its use in clinical practice.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5):4-6; 1988.

[30 references; 11 in English]

Operational Medicine, Clinical Practice; Cardiovascular and Respiratory Systems; Body Fluids
Humans, Review Article

Weightlessness Simulation, Dry Immersion

Abstract: This paper reviews the physiological effects of the "dry" immersion technique of weightlessness simulation. In this method the subject is placed on the surface of a special waterproof sheet that completely protects him from contact with the water and, because of its high elasticity, becomes immersed. The following effects have been attributed to immersion: Increase in central blood volume; 30% increase in cardiac minute volume on day 1 due to 35% increase in cardiac stroke volume; increase in cardiac ejection after 1 hour; early increase in circulating blood volume followed by decrease; decrease in volume of interstitial fluid and erythrocyte mass; heightened excretion of electrolytes, particularly sodium and potassium; increased capillary permeability; decreased aldosterone in blood; blockade of antidiuretic hormone leading to decreased reabsorption of water and sodium in the renal tubules and increased diuresis; decreased afferent stimulation of the central nervous system from peripheral receptors in the muscles, blood vessels, and organs leading to excitability of the reticular formation and thus the cerebral cortex; increased tonus of the parasympathetic nervous system; decreased activity of the parasympathetic nervous system. Dry immersion treatments have or can be used to treat diseases and conditions such as: cardiovascular disease (by virtue of its hypotensive affect); disease accompanied by disruption of fluid-electrolyte metabolism; cirrhosis of the liver (by virtue of its diuretic effect); edema of renal origin; and circulatory insufficiency leading to edema.

PERCEPTION

(See also: Developmental Biology P976; Human Performance P971)

PAPERS:

P948(21/89)* Sokolov AI, Barmin VA

The effect of unloading of the antigravity system on perception and reproduction of the gravitational vertical in response to optokinetic stimulation.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 24-27; 1988.

[10 references; 6 in English]

Perception, Vertical

Humans, Males

Neurophysiology, Dry Immersion, Optokinetic Stimulation, Proprioceptive Stimulation

Abstract: Subjects in this experiment were 11 healthy males aged 26-34. Proprioceptive unloading was modeled using dry immersion in water for a period of 3 days. Testing was conducted in the baseline period, on days 1 and 3 of immersion, and immediately after emergence from the immersion tank. Optokinetic stimulation was produced by a device worn on the subject's head. Inside the stimulator helmet, at a distance of 15 cm from the subject's eyes was a moving tape diffusely covered with circles 2 to 8 mm in diameter, creating a visual field without markers of the vertical. The field of view was 4° and rate of movement of the tape was 180, 200, 220, and 240 mm/sec corresponding to a rate of 25, 28, 31, and 34°/sec. The tape always moved from left to right at a given rate for 1 minute. Normative data suggest that the temporal threshold for disrupting perception and reproduction of the vertical at the speeds used is 20-40 seconds. Testing began with a optokinetic stimulation rate of 25°/sec. On command the subject adjusted a lever in the stimulation device to correspond to the gravitational axis of his body. Error was measured in angular degrees. During optokinetic stimulation eye movements were measured using standard electrooculography. Parameters recorded included latent period, and amplitude and frequency of optokinetic nystagmus. To study the role of proprioceptive stimulation, the same parameters were measured in 3 subjects at rest and during artificial support loading created by strapping a wooden platform to the feet with bungee cords. The platform, which created a force 1/3 of body weight, was used on day 1 and 3 of immersion for a period of 5 minutes.

On the basis of baseline data subjects were divided into two groups. Group 1 (N=7) had a longer latency for optokinetic nystagmus (6.24 sec) and a more accurate perception of the vertical (+4, -5°). In the second group (4 subjects) latency period was shorter (4.7 sec), and error greater (+5 to -9°). Amplitude and frequency characteristics of nystagmus within each group were essentially identical for all speeds of stimulation, equalling 80.6 μ V and 1.0 strokes/sec and 80.3 μ V and 0.9 strokes/sec. in groups 1 and 2, respectively. After 1 hour of exposure to immersion there were changes in all subjects in perception of vertical, averaging +5 and -7°. Increase in error at optokinetic stimulation rate of 34° was 20% higher than at stimulation rate of 25°. Nystagmus latency decreased in both groups, but no significant changes occurred in amplitude or frequency of nystagmus. On day 3 effects on perception of the vertical had decreased by a mean of 15% compared to those on day 1. Three hours after emergence from the immersion tank, perception of the vertical had improved but remained less accurate than during baseline period. Nystagmus parameters were virtually identical with baseline. Artificial support used in 3 subjects altered the situation. On days 1 and 3 of treatment, their perception of the vertical was identical to baseline.

PERCEPTION

The authors conclude that their results confirm existing ideas about the importance of proprioceptive stimulation in the interaction of visual, vestibular and proprioceptive systems in creating appropriate body orientation in space during exposure to decreased gravity.

Table: Changes in temporal, speed and frequency characteristics of optokinetic nystagmus in 2 groups of subjects under conditions of immersion hypokinesia

Figure: Effects of immersion hypokinesia on the function of perception of the gravitational vertical

PSYCHOLOGY

(See also: Adaptation P969, BR15; Developmental Biology M143; Human Performance, All Entries; Perception P948; Reproductive System P955)

PAPERS:

P963 (21/89) *Kozlov AT, Tsetsura VN.

Behavior of Limnephilus sp. caddis fly larvae in response to drastic changes in the weight of building materials.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 88-90; 1988.

[7 references; 2 in English]

Psychology, Instinctive Behavior; Adaptation

Insects, Caddis Flies, Larva

Altered Weight of Building Materials

Abstract: The goal of this experiment was to investigate adaptation of behavior to conditions in which materials used by animals to build become partially weightless. Subjects were larvae of caddis (*Limnephilus sp.*) flies, which build cases for themselves out of particles of plant detritus, and the shells of small mollusks. Observations were made under laboratory conditions. Larvae were removed from petri dishes and given small particles of plastic foam as building materials. These particles floated on the surface of the water. The cycle of case building, which normally involves 10 stages, was observed through a microscope for 40 individuals. The cases were weighed after completion. The larvae completed all stages of the building process, although at least six of these steps had to be altered because the particles to be used floated rather than sank. As the animals continued to seize and test the particles, their movements grew increasingly exact and rapid. Time spent on one particle decreased from 2-2.5 to 0.5 minutes over the session. Although the stereotypy of the building process was retained in general there was evidently some adaptive flexibility to the pattern. New stages in the process occurred (e.g., reorientation), others ordinarily present (building of an "anchoring" structure) were eliminated. The authors argue that the adaptability to some aspects of weightlessness shown by this larvae make them suitable subjects for flight experiments.

Figure 1: General schema of the building behavior of caddis fly larvae in the construction of cases out of ordinary and plastic foam particles

Figure 2: Comparisons of the weights of building particles and completed cases

P975(21/89)Serova LV(U.S.S.R.), Alberts J, Keefe D (U.S.A.)

The behavior of female rats while nursing their young..

In: M143(21/89) Gazenko O.G. (editor) Ontogenez mlekopitayushchikh v nevesomosti [*Ontogeny of Mammals in Weightlessness*]

Moscow: Nauka; 1988; pages 79-82.

Psychology, Maternal Behavior, Reproductive System, Nursing
Rats, Mothers
Space Flight, COSMOS-1514

Abstract: Female rats were exposed to weightlessness on COSMOS-1514 on days 13-18 of pregnancy. After completion of their space flight, they began to gain weight rapidly, compensating for the lag occurring during flight. However when they were weighed on the day after giving birth (day 6 of the adaptation period) their weight averaged 20 g less than the weight of the vivarium control group. This intergroup difference persisted until the end of the observation period (day 20 of the nursing period), but diminished somewhat between days 13 and 18 of readaptation.

During the first 10 days postflight, the animals continued to be given *ad lib* access to special feed. No significant differences in daily consumption of feed was noted among groups at any point. There were no reliable intergroup differences in the amount of food consumed by a rat per unit body weight, nor in food consumption per unit total biomass (mother + offspring). Starting on day 10 of the lactation period, the animals were put on a mixed diet in which carrots, greens, and curds supplemented the special feed; this complicated exact measurement of the amount of food eaten on subsequent days. Consumption of water, measured daily, was low, due to the high water content of the food and was virtually identical in the experimental and control groups.

Starting on the day after birth of the litter, the animals were housed in special cages designed for study of maternal behavior. The cages, depicted in Figure 23, consisted of a nursery (A) and a feeding chamber (B). The floor of the cage contained a scale which made it possible to determine the amount of time the mother spent in each of the chambers. The floor of the nursery contained a temperature sensor and the roof of the cage above the nest held a microphone for recording the intensity of ultrasound emitted by the babies when the mother left the nursery. These parameters are relatively good indicators of a mother's care of her offspring; they follow a diurnal rhythm and closely correlate with each other. If the relationship between the mother and offspring is normal, when the mother leaves the nursery, the ultrasound emitted by the babies increases in intensity; the louder the cries the sooner the mother's return.

The experimental apparatus included a computer device, which recorded and processed information from the cage every 15 minutes around the clock, and video cameras, which photographed the animals while they were in the cages. Video data was subsequently processed by computer.

Figure 24 depicts the time the experimental and control rats spent daily in the nursery over the 18 days of observation during the lactation period. Both the experimental and the control females showed normal patterns of change in this parameter: There was a gradual decrease in the time the mother spent in the nursery, from 90% on day 1-2 after giving birth to 60% on day 15-16. However, for virtually every observation day, the time the flight mothers spent in the nursery was 5-10% greater than that spent by the vivarium control subjects. This difference is likely to be related to the smaller sizes of the rats in the flight group and their offspring.

Figure 25 presents a detailed hour-by-hour record of maternal behavior parameters for one mother from the flight and one from the vivarium group on day 6 after birth. Both curves demonstrate normal behavior for mother rats: diurnal rhythms in time spent in the nursery; and the negative correlation between the time spent by the mother in the nursery and intensity of the cries emitted by the offspring.

Thus, soon after return to Earth, mother rats exposed to weightlessness from day 13 to day 18 of pregnancy were capable not only of giving birth to offspring, but of caring for them adequately during all stages of the lactation period. Despite the stress reaction developing during the flight and at reentry, the major characteristics of maternal behavior in the experimental group were within the limits of the physiological norm.

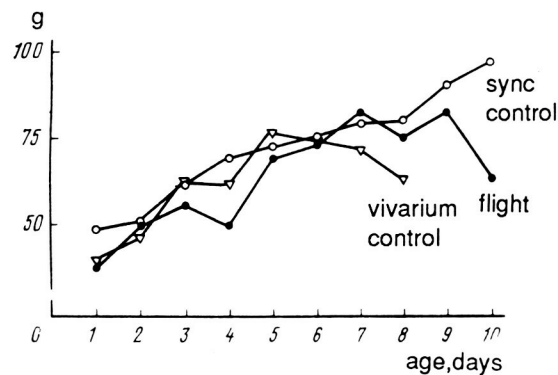


Figure 22: Food consumption by female rates during the initial nursing period

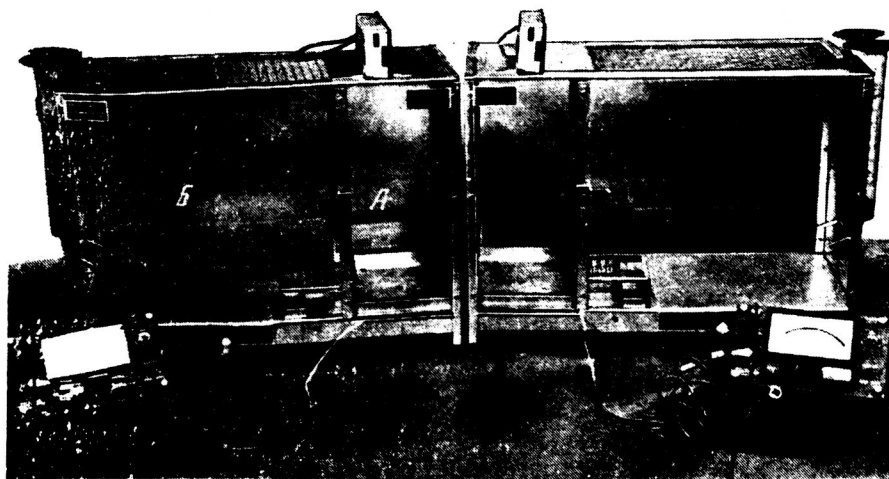


Figure 23: Cages for the study of maternal behavior in rats

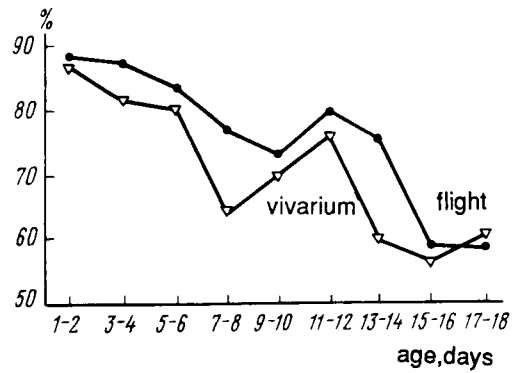


Figure 24: Portion of the day spend by mother rats in the nursery during the nursing period

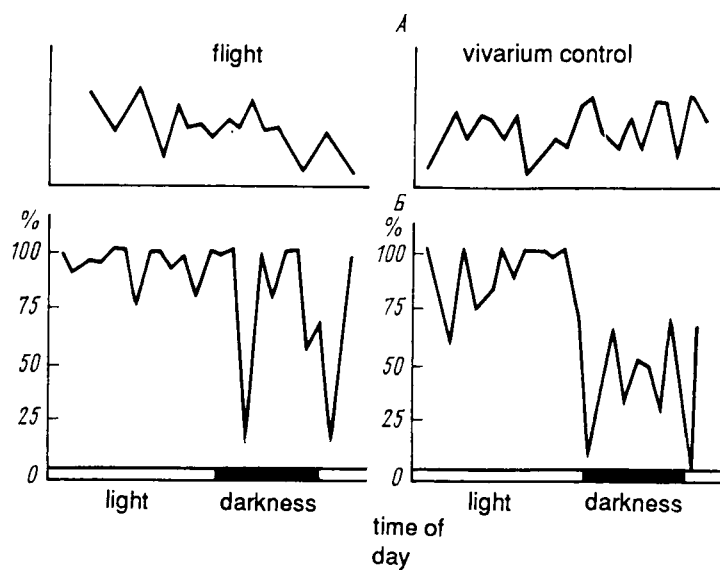


Figure 25: Day 6 of the postnatal period. Reactions to sound made by the neonate rats (A) and time spent in nursery (B) in experimental and control groups

P978(21/89) Ananassenko ZI, Kuznetsova MA, Serova LV, Korotkova (U.S.S.R.).

The development of behavioral reactions and work capacity of the higher nervous system.

In: M143(21/89) Gazenko O.G. (editor) Ontogenez mlekopitayushchikh v nevesomosti [*Ontogeny of Mammals in Weightlessness*]

Moscow: Nauka; 1988; pages 104-110.

Psychology, Behavioral Reactions, Neurophysiology, Higher Nervous Activity; Emotionality; Developmental Biology, Postnatal Development
Rats, Early Development
Space Flight, COSMOS-1514, Prenatal Exposure

Abstract: This study involved observations of development rats exposed to weightlessness on days 13-18 of prenatal ontogeny. The focus here was on work capacity of the higher central nervous system and behavioral reactions of animals at various stages of postnatal development, up to the period of sexual maturity.

When the rats were 30, 51-53, and 88 days old, assessments were made of emotionality and orienting/exploratory reflexes in a round "open field" 90 cm in diameter, divided into 3 zones (from the center to the periphery) and 32 areas. Parameters measured included: horizontal and vertical motor activity, frequency of entering the center area of the field and relative length of the path taken to the center of the field, special orienting reactions (sniffing, standing on the hind legs), grooming, and amount of urine and excrement. The results obtained are presented in Table 32.

When studied at age 30 days, the flight rats showed reliably diminished (compared to the vivarium and synchronous controls) frequency of visiting the central zones of the field, together with diminished length of the path to these zones, as well as in the number of orienting reflexes. Total motor activity (horizontal and vertical) was less in the experimental group than in the vivarium control group, but an analogous decrease was noted in the synchronous control group. The greatest difference between the experimental and control groups was noted at days 51-53 of their lives. At this stage the animals developing under conditions of weightlessness showed substantial and reliable decreases in all indicators of exploratory activity in the "open field." When the animals reached the age of 3 months, the differences between groups had diminished and were no longer significant for any parameter.

At 51-53 days of age the male rats of the experimental group displayed elevated emotional excitability, which was manifest in a significant increase in quantity of excrement produced in the "open field." A tendency for this parameter to be elevated was also noted in the synchronous control, but to a much smaller extent than in the flight group, and the difference between the flight and synchronous groups was statistically significant. No differences in this parameter were found in the female rats (Figure 38). Another parameter usually considered a sign of emotional excitability, frequency and duration of grooming, displayed no intergroup differences in the "open field" test on days 51-53. When testing was conducted when the rats were 3 months old, no intergroup differences were found in parameters of emotional excitability.

Analysis of the course of the animals' adaptation to "open field" conditions observed during 3 consecutive days (51-53 of life) showed no intergroup differences. When the reactions of 3-month-olds to an extreme stimulus (sound) were tested in the open field situation, no reliable intergroup differences were observed.

When the rats were 2 months old (58-72 days of life), their behavior in a Dombrovskiy maze was studied. This maze consisted of six parallel branches, and a start and goal box. Each branch had several locked doors and one unlocked door. After familiarization with the maze

environment, the animals were given the task of finding the single closed, but not locked, door in each branch, to gain access to the goal box to obtain food. During task performance, the following parameters were recorded: number of balks (refusal to traverse the maze); latency period (time it took to leave the start compartment); number of errors (attempts to go through a locked door or pushing against the dividing partition); time to traverse the maze; number of times the animal stood up on its hind legs (a response associated with loss of orientation); frequency and duration of grooming; and movements away from the goal box. Behavior was studied in the Dombrovskiy maze over 11 consecutive trials, each trial contained three tasks. After trial 8, the goal path was changed, unlocked doors were locked and one previously locked door in each branch was unlocked.

During the second task of the fifth trial an external inhibitory stimulus— a bell — was rung after 5 seconds. The results obtained are presented in Table 33. The experimental and control group contained the same number of animals unable to acquire the algorithm for running the maze. The difference lay only in the fact that the failure of the majority of rats in the flight group was manifested sooner than those in the control group — the former failed during the first stage of training, when all the doors were open.

Among the animals learning the maze, the number of balks was higher in the flight group than in the vivarium control, but the former did not differ from the synchronous control. It is interesting however, that balks occurred in both control groups in the initial branches, while the flight animals balked toward the end of the maze. In 50% of the cases (compared to 18-20% in the control) balks occurred in the last branch before the goal box. The difference between experimental and control groups in this parameter was statistically significant ($p < 0.001$).

The duration of the latency period and the number of errors occurring while running the maze were the same in all three groups (Cf. Table 33). The time required to reach the goal was significantly longer in the flight animals than in either control group.

It is noteworthy that the flight animals displayed an elevated number of grooming responses (e.g., washing, scratching) in the maze compared to the vivarium and synchronous control (Figure 39), evidently due to broad irradiation of excitation against a background of attenuated internal inhibition. The experimental animals also showed a high number of inappropriate movements, i.e., behaviors not relevant to obtaining the primary goal (obtaining food): standing up leaning against the wall, running back and forth in the branches, running through the branches without attempting to open the doors, pushing the wall in a direction opposite to the goal box, nosing the open door multiple times, etc. The number of such movements did not decrease from trial to trial, as with the control group, but remained at a constant level or even increased, which was evidently associated with inertia in the irradiated excitation.

The diminished flexibility of neural processes in experimental animals also attests to their greater reaction to the effects of the external inhibitory stimulus. The process of switching attention away from the reactions evoked by this stimulus was more difficult and took more time in the experimental than in the control animals. For the former, the number of errors, time required to run the maze, number of inappropriate movements, and amount of grooming all increased substantially. The greatest differences occurred as a result of external inhibition, i.e., in the trial following presentation of the inhibitor. While in each successive trial the control animals demonstrated the expected decrease (or insignificant increase) in number of inappropriate movements and errors, these parameters increased insignificantly in the experimental group. Utilization of past experience in the new situation was not disrupted in the flight animals; they transferred the skill of running the maze [to a new task] as readily as the control animals. None of the parameters recorded were greater in the flight than in the control

group. However, the experimental animals did not demonstrate a decrease from trial to trial in the number of inappropriate movements, as occurred in the control groups.

The weakness of the inhibition process, tendency to irradiation of excitation, and decreased lability of fundamental neural process fostered more frequent reexcitation and the occurrence of neurotic states in the flight rats.

The changes observed were not specific (to the particular space-related experimental conditions) and have been shown to be associated with the effects of a large variety of factors: irradiation, hypoxia, pharmacological agents. Examination of the animals of the synchronous control group showed that in this experiment the dynamic factors associated with flight (with the exception of weightlessness) also had some effect for the establishment of behavioral reactions in the offspring of exposed animals.

All the results obtained in this portion of the research program support the conclusion that the effects of space flight factors on developing fetuses exposed on days 13-18 of the prenatal period do not induce gross disorders of higher nervous activity. Animals developing under conditions of weightlessness were virtually normal in their ability to orient themselves in the new environment, to master the behavioral algorithms required, and to transfer what they had learned to a new situation. The flight group did not differ from control animals in the number of subjects mastering the appropriate behavioral algorithm for the mazes, number of balks, errors in performing the tasks, or duration of latency. The animals in all groups were approximately equal in their ability to transfer a learned response.

However, the behavioral reactions of the experimental animals were not completely identical to those of controls. Rats developing in space showed shifts in subtle, easily disrupted mechanisms of internal inhibition; a weakening of equilibrium; and a decrease in the flexibility of the fundamental neural processes. The phenomena observed may be considered a result of attenuation of the inhibiting effects of the cortex on subcortical structures, evidently due to delay in maturation of functional cortical structures resulting from prenatal exposure to space flight factors. The changes noted may be the reason for the decreased work capacity of the central nervous system, which would in turn decrease adaptability to environmental conditions, especially in a difficult situation or when time is limited.

Table 32: Postnatal ontogeny. Exploratory activity of rats in an "open field"

Grp	1	2	3	4	5	6	7
30 days							
F	83.6 pv<0.05	6.9 ps<0.001 pv<0.01	4.2 ps<0.01 pv<0.05	8.3 pv<0.05	13.8 ps<0.05 pv<0.01	5.5 ps<0.05	9.8 pv<0.05
SC	95.0	10.3	7.5	10.6	16.2	2.2	11.2
VC	103.3	8.0	5.3	13.7	19.4	1.5	5.9
52 days							
F	73.3 ps<0.01 pv<0.01	6.6 ps<0.001 pv<0.001	4.2 ps<0.001 pv<0.001	8.2 ps<0.001 pv<0.01	10.4 ps<0.001 pv<0.01	1.9 ps<0.05	33.0 ps<0.05
SC	94.9	12.0	11.7	15.6	21.2	2.7	37.6
VC	97.8	12.1	9.0	12.5	16.9	2.0	22.0
88 days							
F	99.8 pv<0.05	12.6 ps<0.05	8.4 pv<0.05	15.1	6.8 pv<0.05	0.06	14.2 ps<0.05
SC	106.9	10.5	9.1	12.8	19.5	0	19.3
VC	108.5	13.5	12.7	14.9	9.7	1.8	6.0

1 - Distance traversed in the "open field," arbitrary units; 2 - Visits to central zone;
 3 - Relative length of route to center, %; 4 - Number of times standing up against the wall; 5 - Orienting reflexes;
 6 - Excretion, arbitrary units; 7 - Duration of grooming.

Table 33: Behavioral parameters of animals in Dombrovskiy maze

Grp	Rats unable to master maze, %	Number of balks, %	Latency pd., secs	Number of errors	Solution time, secs
F	31.2	9 pv<0.1	2.4 ps<0.05	16.8	85.1 pv<0.001 ps<0.05
SC	41.8	13.6	3.5	16.3	70.8
VC	33.3	3.9	2.2	15.2	61.4

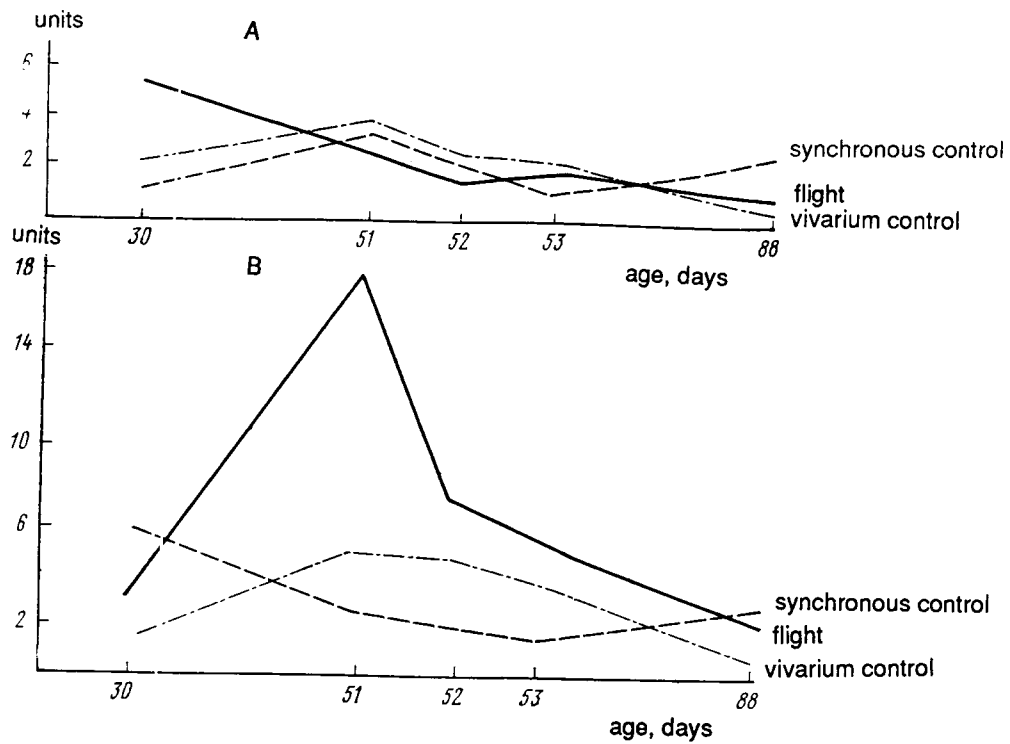


Figure 38: Amount of excrement in females (A) and males (B) in "open field"

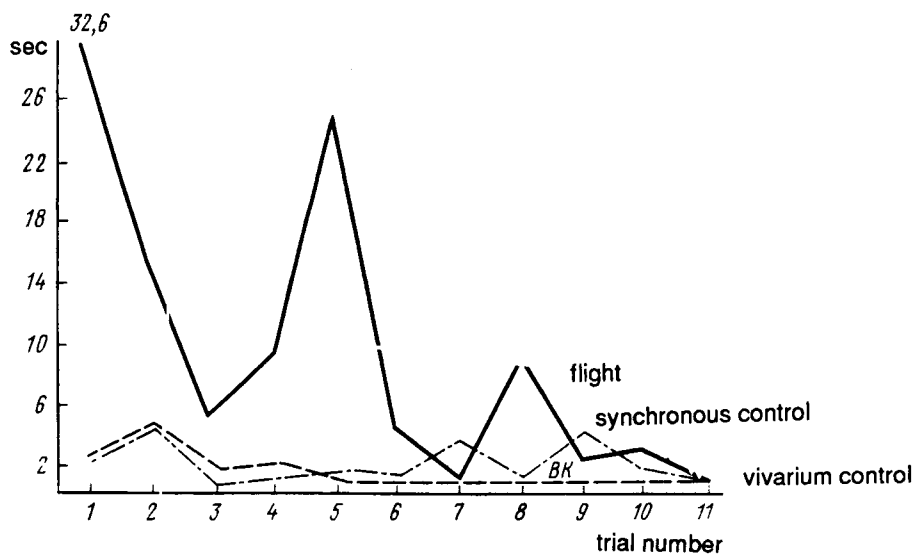


Figure 39: Time spent grooming in animals in the flight and control groups while running a Dornbrovskiy maze

P979(21/89) Serova LV (U.S.S.R.).

Reactions to stress tests at various stages of postnatal ontogeny.

In: M143(21/89) Gazenko O.G. (editor) Ontogenez mlekopitayushchikh v nevesomosti [*Ontogeny of Mammals in Weightlessness*]

Moscow: Nauka; 1988; pages 110-112.

Psychology, Stress, Stress Test Response, Developmental Biology,
Hematology

Rats

Space Flight, COSMOS-1514, Prenatal Exposure; Immobilization

Abstract: Rats exposed to space for 5 days during prenatal development were subjected to a stress test at 30 and 90 days of age. Stress was created by placing the animals in immobilization cages of a size designed to accord with individual body size. Duration of exposure was 2.5 hours. Stress reaction was estimated on the basis of a cytogram of peripheral blood, which was taken twice, immediately before and immediately after immobilization. A control group was also tested.

Both the control and the experimental animals at both points in time tolerated the stress test well; their general state upon removal from the cage was satisfactory. The animals of the control group at 30 days old already displayed the reaction typical of adult rats: decrease in concentration of lymphocytes in peripheral blood and neutrophilia; the ratio of lymphocytes to neutrophils dropped from 3.8 (before the test) to 1.4 after its termination. Anomalous changes — increase in the concentration of lymphocytes and decrease in the concentration of neutrophils with segmented nuclei — were noted after the stress test in fewer than 10% of the cases and effects were slight when they did occur (within the limits of 1 thousand/mm³).

During this same developmental period, rats of the flight group developed neutrophilia comparable in severity to that of the control animals. However, instead of the lymphopenia observed in the control, 83% of the experimental animals showed significant lymphocytosis — the concentration of lymphocytes increased by a mean of 3.2 thousand/mm³. The ratio of lymphocytes to neutrophils decreased in the majority of experimental rats; however, in 27% of the cases there were anomalous reactions in which the lymphocytes/neutrophil ratio either did not change after stress or increased (Table 34).

When tested at the age of 90 days, the majority of animals in both the control and experimental groups displayed the normal blood system reaction to stress. At the conclusion of the stress test, concentration of lymphocytes in peripheral blood decreased, equally in control and experimental animals, and the proportion of anomalous reactions was identical (Cf. Table 34). Neutrophilia was observed both in experimental and control animals; however, it was significantly more severe in flight rats; proportion of anomalous reactions was identical. The lymphocyte/neutrophil ratio decreased at the end of the stress test in all animals in both groups; no significant intergroup differences in severity of the reaction were noted

Thus, both the experimental animals and the controls, at both periods of observation, satisfactorily endured the stress associated with temporary restraint of movement.

When the animals were tested at the age of 90 days, appropriate reaction to the stress tests — lymphopenia, neutrophilia, decreased lymphocyte/neutrophil ratio — were observed in an equal number of experimental and control animals. The sole difference between the groups at this period was the greater extent of neutrophilia in the experimental animals. It should be noted that initial (pretest) concentration of neutrophils was identical in the experimental and control

animals (3.0 and 3.2 thousand/mm³, respectively). Thus the response to the stress tests in the concentration of segmented nuclei neutrophils in the blood of the experimental animals (7 thousand/mm³) was substantially greater than in the control (5 thousand/mm³).

When the animals were tested at 30 days old the experimental group contained a higher percentage of animals manifesting an anomalous reaction to stress: increased concentration of lymphocytes in blood (83% of the cases, $p < 0.002$) and an increased lymphocyte/neutrophil ratio (27% of the cases, $p < 0.05$). The reaction of lymphocytes to stress occurs in two stages: the release of lymphocytes into the blood from the thymus and spleen; and their migration into bone marrow and tissue where they serve to stimulate hemopoiesis and activate the mitotic activity of tissues, and also as a source of anabolic materials. It appears that in the 30-day-old rats in the experimental group, in contrast to the control, only the first stage of this reaction occurs, which may be considered a sign of some retardation in development, since later — at 3 months old — both stages of the reaction occur in the experimental as well as the control group.

It should be noted that the initial (pretest) examination of 30-day-old flight rats revealed a lower concentration of lymphocytes (6.9 thousand/mm³ compared to 10.8 thousand/mm³ the control, $p < 0.01$) and neutrophils (1.7 thousand/mm³ compared to 3.5 thousand/mm³ in the control, $p < 0.01$), in the experimental group. This may have been the source of the difference in concentration of blood cells in response to stress.

The data obtained provide a rather clear picture of differences in the reactivity of the blood system to stress tests between experimental animals developing in weightlessness and their control counterparts. Because the number of animals developing under conditions of weightlessness was so limited, they had to be kept alive for other studies and could not be dissected to evaluate the state of the lymphoid organs, bone marrow, and hormonal status after the stress test.

Table 34: Reactions to immobilization stress in animals spending a portion of the prenatal period in weightlessness

		Changes in peripheral blood					
Gp	n	Number of lymphocytes		Number of neutrophils with segmented nuc		Lymphocyte/neutrophil ratio	
		Thous/mm ³	Anom.,%	Thous/mm ³	Anom.,%	Thous/mm ³	Anom.,%
30 days							
F	12	+3.2±0.3	83	+3.2±0.5	17	-2.6±0.4	27
		p<0.001	p<0.001				p<0.05
VC	12	-3.0±0.4	10	+3.4±0.4	10	-2.4±0.4	0
90 days							
F	12	-6.1±0.6	17	+4.9±1.1	17	-3.0±0.6	0
				p=0.05			
VC	12	-5.4±0.1	17	+2.4±0.5	17	-2.5±0.3	0

REPRODUCTIVE SYSTEM

(See also: Developmental Biology P972, P974, M143; Neuorphysiology P967; Psychology P975)

PAPERS:

P955(21/89)* Baykova OV.

Cytophysiological parameters of the state of the reproductive organs of male rats after 7 days of immobilization stress and 7 days of hypokinesia.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(5): 56-59; 1988.

[12 references; none in English]

Reproductive System, Reproductive Organs, Cytophysiological Parameters

Rats, Male

Hypokinesia, Psychology, Immobilization Stress

Abstract: Three groups of male Wistar rats, aged 3 months, served as subjects in this experiment. One group served as the controls. Rats in one experimental group were immobilized, probably through rigid fixation, for 2.5 hours a day for 7 days. A second group was housed in immobilization cages for a like period. There were 7 rats in each group. At the termination of the experimental period, the animals were sacrificed and the weight of their testes, epididymis, and seminal vessels measured. Concentration of spermatozoids was measured in a suspension of epididymus, while numbers of atypical spermatozoids and plasmatic bodies were counted in smears made from the suspension. Identification and count of spermatogenic cells was performed on smears made from testes homogenate stained azure with II-eosin. The following parameters were measured:

- distribution of various types of sex cells (spermatogonia, spermatocytes, spermatids), Leydig's and Sertoli cells (per 3000 cells);
- Sertoli cellular index for spermatogenic cells, ratio of number of cells of each type to Sertoli cells;
- spermatogenesis stress; ratio of the number of all spermatogenic cells to all Sertoli cells;
- percentage of multinucleated sex cells: spermatogonia (per 300 cells), spermatocytes (per 500 cells), and round spermatids (per 1000 cells);
- percentage of multinucleated spermatogones of type B with distribution by number of nuclei in a cell (per 1000 cells).

Student's t was used to test data for significance.

Under both immobilization and hypokinesia, body weight decreased by 17-18%. Animals undergoing immobilization stress also showed decreased weight of the reproductive organs. Concentration of spermatozoids in suspensions of the epididymus was decreased by over 40% in both groups. The relative quantity of atypical elements in smears from the epididymus was elevated by a factor of 2.5 and 4 for the immobilization and hypokinesia groups, respectively. Both experimental groups showed a reliable decrease in the number of the youngest male sex cells in percent of distribution of sex cells and in Sertoli index. Sertoli index for spermatocytes and spermatids indicated a decrease in the former in both groups and a decrease in the latter in group 2. However, these effects were not detectable in the proportional distribution of these cells. Spermatogenetic stress, the major index reflecting spermatogenic production, showed a significant (14%) decrease in the total number of spermatogenic cells in the animals of group 2 and a tendency to decrease (10%) in group 1. There was a significant decrease in Leydig's cells in both experimental groups. The authors suggest that in the immobilization group the

decrease in concentration of spermatozoids in the epididymus and the simultaneous decrease in seminal vessel weight are associated with an increase in spontaneous ejaculation in this condition. Under hypokinesia, however, the weight of the seminal vessels remained constant while the concentration of spermatozoids decreased. The authors attribute this effect to decreased number of spermatids in the testes. Percentage of multinucleated spermatogonia was elevated by 7 and 2.2% in the immobilization and hypokinesia groups, respectively; number of multinucleated spermatocytes were increased by 1.4 and 1.8%. Multinucleated rounded spermatids were elevated (by 2%) in the hypokinesia group. The elevation in multinucleated spermatogonia was primarily attributable to type B — the last in the series of mitotic divisions. The authors conclude that the changes in reproductive organs noted after space flight may be partially due to stress effects. However, it should be remembered that ground-based models of stress and hypokinesia, and particularly immobilization stress, induce more severe changes in reproductive organs than does space flight.

Table 1: Parameters of the state of the reproductive organs of male rats after 7 days of immobilization stress or hypokinesia

Table 2: Cytological parameters of the state of the spermatogenic epithelium in the testes of rats subjected to 7 days of immobilization stress or hypokinesia

Figure 1: Multinucleated sex cells

Figure 2: Multinucleated Type B spermatogonia

P973(21/89) Serova LV, Denisova LA, Lavrova LA, Makeyeva VF, Natochin YuV, Pustynnikova AM, Shakhmatova Yel.

Parameters of the reproductive function of the animals: Fetal and placental characteristics.

In: M143(21/89) Gazenko O.G. (editor) Ontogenez mlekopitayushchikh v nevesomosti [*Ontogeny of Mammals in Weightlessness*]

Moscow: Nauka; 1988. Pages 71-74.

Reproductive Biology, Reproductive Function, Placenta; Developmental Biology, Fetuses, Musculoskeletal System, Bone
Rats, Females, Pregnant
Space Flight, COSMOS-1514

Abstract: In this study, female rats were exposed to weightlessness on COSMOS-1514 on days 13-18 of pregnancy. Although they were found to weigh less than control animals and show a number of other adverse effects, their reproductive function was virtually unaltered. When the rats were dissected on day 18 of pregnancy, the flight group did not differ reliably from controls in preimplantation or total embryo deaths (Table 21). The number of living fetuses averaged 13 in the flight and synchronous groups and 12 in the vivarium control condition. No dead fetuses were found in any of the groups; however, the flight and synchronous control females produced more fetuses and placentas with bleeding. The authors suggest that this was caused by reentry factors. No other developmental anomalies were noted.

The placentas of the flight group were smaller and weighed less. Histologically these changes were attributable to the labyrinth portion of the placenta — the site where the most intensive metabolic interchange between the mother and fetus occurs; the thickness of the spongy layer was altered. Hydration of placental tissue was identical for all groups. Concentration of potassium in placental tissue was depressed in all flight animals, while concentration of sodium was elevated, suggesting a diminished proportion of cellular elements. Concentrations of calcium and magnesium were the same in placentas of all animals. No differences were found between the experimental and control groups with respect to concentrations of DNA, RNA, protein, or glycogen in placental tissue (Table 22).

Mean weight of the fetuses was 0.84 g for the flight group, 0.92 g for the vivarium group and 0.94 g for the synchronous group ($p < 0.05$); fluid content in fetal tissues was reliably higher in the flight group than in the controls (Table 23). This can be considered a sign of some developmental retardation since, fluid content decreases progressively as the fetus grows. No differences were found among groups in concentrations of sodium, potassium, calcium, or magnesium in fetal tissue. At the same time when their skeletons were measured, the flight fetuses showed a developmental retardation manifested in a decrease in the size of ossification sites in virtually all developing bones by 13-20% compared to corresponding parameters for the control groups (Figure 20), i.e., although concentration of calcium was normal in fetal tissues, its inclusion in developing bone was delayed.

Study of metabolism of nucleic acids and proteins in fetal tissues revealed no reliable differences among the groups in concentration of DNA, RNA, or protein (Table 23). Despite severe symptoms of a stress response in the mother (including changes in catecholamine metabolism), the activity of tyrosine-hydroxylase—the key enzyme for synthesizing catecholamines in the adrenal glands of fetus — was unaltered (Table 23). It is noteworthy that there was a reliable decrease in the concentrations of hemopoietic stem cells in the livers of flight fetuses, since at this stage of development the liver is the major hemopoietic organ (Table 23).

On day 18 of pregnancy the total weight of the fetuses developing in each female in weightlessness was equivalent to that of the vivarium control, equalling 11.40 and 11.47 g, respectively. Thus, despite the significant loss of weight in the mother, evidently due to the activation of catabolic processes, these animals were able to activate anabolic processes associated with the growth and development of their fetuses to the same extent as control mothers.

Table 21: Parameters of reproductive functions of female rats exposed to weightlessness during pregnancy

Group	n	Corpus luteum, n	Implantation sites, n	Resorptions, n
Flight	5	15.8 ± 1.0	14.8 ± 0.7	1.2 ± 0.4
Synchronous	5	16.0 ± 0.8	14.4 ± 0.7	1.0 ± 0.4
Vivarium	7	14.9 ± 0.4	13.0 ± 0.8	0.6 ± 0.3

Group	Live fetuses n	Dead fetuses n	Preimplantation deaths, %	Total embryo deaths, %
Flight	13.6 ± 0.8	0	5.8 ± 2.6	13.4 ± 4.1
Synchronous	13.4 ± 1.0	0	9.9 ± 2.8	16.4 ± 4.4
Vivarium	12.4 ± 0.9	0	12.5 ± 4.7	16.4 ± 4.8

Table 22: Placental characteristics on day 18 of pregnancy

Parameter	Flight	Group Synchronous	Vivarium
Weight, g	0.31 ± 0.02 p(s) < 0.05	0.37 ± 0.01	0.38 ± 0.025
Thickness of labyrinth portion, mm	2.12 ± 0.06 p(s, v) < 0.001	2.45 ± 0.05	2.65 ± 0.05
Thickness of spongy portion, mm	0.87 ± 0.06	0.80 ± 0.03	0.90 ± 0.04
Fluid, kg/kg dry weight	5.97 ± 0.19	5.95 ± 0.15	5.96 ± 0.14
Na, mequiv/kg dry wt	504.1 ± 12.8 p(v) < 0.05 p(s) < 0.002	431.9 ± 16.4	466.0 ± 11.0
K, mequiv/kg dry wt	394.2 ± 8.5 p(v,s) < 0.001	436.0 ± 6.5	441.7 ± 6.6
Ca, mequiv/kg dry wt	57.8 ± 11.3	41.4 ± 4.9	52.9 ± 7.6
Mg, mequiv/kg dry wt	71.8 ± 3.5	69.5 ± 2.1	76.4 ± 1.8
DNA mg/g moist tissue	2.51 ± 0.14 p(v) < 0.05	2.88 ± 0.12	2.29 ± 0.15
RNA mg/g moist tissue	7.50 ± 0.16	7.15 ± 0.21	7.31 ± 0.19
Protein, ug/g moist tis.	76.4 ± 5.1 p(v,s) < 0.05	59.0 ± 31	83.0 ± 3.3
Glycogen, mg/g	9.3 ± 2.8	9.8 ± 1.9	11.3 ± 2.2

Table 23: Characteristics of fetuses on day 18 of pregnancy

Parameter	n		Flight	Group	
	Mothers	Fetuses		Synchronous	Vivarium
Weight, g	5-7	67-87	0.84±0.03 p(s) < 0.05	0.94±0.02	0.92±0.03
Fluid, kg/kg dry wt.	5-7	9-13	9.55±0.15 p(v) < 0.002 p(s) < 0.02	9.03±0.12	9.04±0.07
Na, mequiv/kg dry wt	5-7	9-12	875.0±13.1	816.7±17.2	863.0±29.8
K, mequiv/kg dry wt	5-7	9-12	637.7±11.5	585.1±12.2	604.8±23.0
Ca, mequiv/kg dry wt	5-7	9-12	209.4±22.2	220 ±17	231.5±24.7
Mg, mequiv/kg dry wt.	5-7	9-12	137.9±4.3	123.9 ± 4.0	150.3±18.7
DNA, mg/g moist wt.	5-7	10	4.05±0.18	4.04 ± 0.15	3.95±0.03
RNA, mg/g moist wt	5-7	10	7.72±0.22	7.75 ± 0.21	7.79±0.27
Protein, ug/mg moist tissue	5-7	10	60.4±3.7	64.5 ± 2.9	63.5±3.5
Tyrosine/hydroxylase, nmole/hr/2 adrenals	5-7	5-6	0.043±0.009	--	0.042±0.008
CFU per 106 liver cells	5-7	5-6	8.2±0.2 p(v) < 0.05 p(s) < 0.002	13.4±1.1	10.5 ±0.8

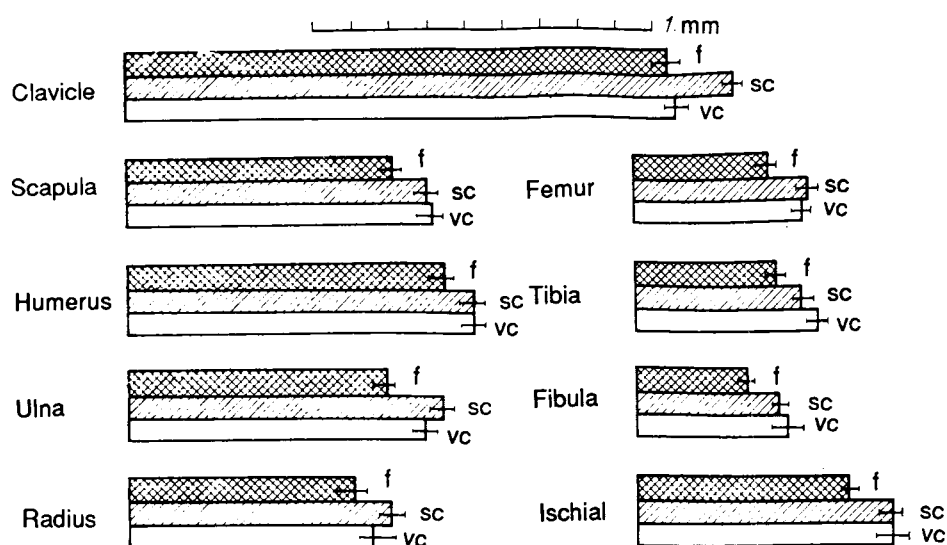


Figure 20: Size of ossification sites in the skeletons of 18-day-old fetuses



Report Documentation Page

1. Report No. NASA CR-3922(24)	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle USSR Space Life Sciences Digest - Issue 21		5. Report Date March 1989	
		6. Performing Organization Code	
7. Author(s) Lydia Razran Hooke, P. Lynn Donaldson, Ronald Teeter, Victoria Garshnek,* and Joseph Rowe, **Editors		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address Lockheed Engineering and Sciences Company 600 Maryland Avenue, S.W. Suite 600 Washington, D.C. 20024		11. Contract or Grant No. NASW-4292	
		13. Type of Report and Period Covered Contractor Report	
12. Sponsoring Agency Name and Address Office of Space Science and Applications National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code EBM	
15. Supplementary Notes *George Washington University, Washington, D.C. **Library of Congress, Washington, D.C.			
16. Abstract This is the twenty-first issue of NASA's USSR Space Life Sciences Digest. It contains abstracts of 37 papers published in Russian language periodicals or books or presented at conferences and of a Soviet monograph on animal ontogeny in weightlessness. Selected abstracts are illustrated with figures and tables from the original. A book review of a work on adaptation to stress is also included. The abstracts in this issue have been identified as relevant to 25 areas of space biology and medicine. These areas are: adaptation, biological rhythms, body fluids, botany, cardiovascular and respiratory systems, cytology, developmental biology, endocrinology, enzymology, equipment and instrumentation, exobiology, gravitational biology, habitability and environmental effects, hematology, human performance, life support systems, mathematical modeling, metabolism, microbiology, musculoskeletal system, neurophysiology, operational medicine, perception, psychology, and reproductive system.			
17. Key Words (Suggested by Author(s)) space life sciences, aerospace medicine, space biology, flight experiments, flight simulations, psychology and human performance, microgravity, USSR, Soviet research		18. Distribution Statement Unclassified - Unlimited Subject Category 51	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 112	22. Price A06